VOL. X JULY AND OCTOBER 1926 NOS. 3 AND 4

Entered as second-class matter January 12, 1924, at the post office at Rio Piedras, Porto Rico, under the Act of June 6, 1900.
Acceptance for mailing at a special rate of postage provided for in section 1103, October 3, 1917, authorized January 12, 1924.

THE JOURNAL

OF THE

DEPARTMENT OF AGRICULTURE

OF

PORTO RICO

MISCELLANEOUS PAPERS

PUBLISHED BY
THE INSULAR EXPERIMENT STATION
RIO PIEDRAS, P. R.

(ISSUED SEPTEMBER 1927)

San Juan, P. R., Bureau of Supplies, Printing, and Transportation, 1927

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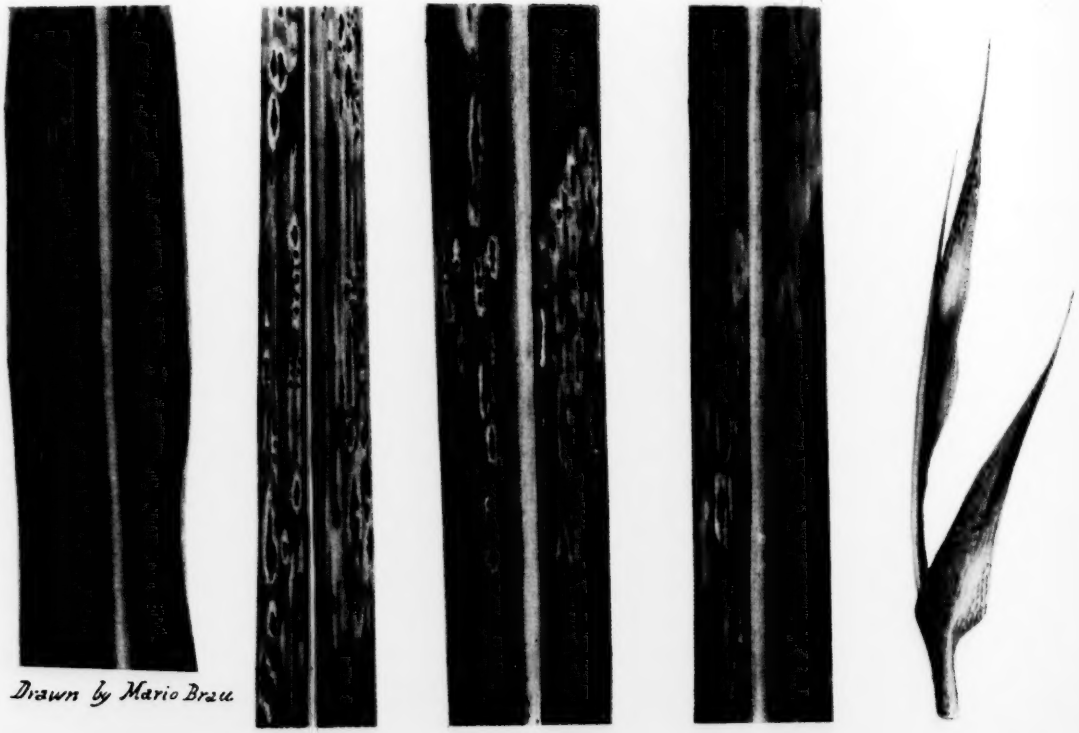
PARTS OF FOUR LEAVES OF SUGAR CANE

The first three show the most common types of injury. The fourth shows the blotch type. Also a young rattoon plant showing severe infection.



Drawn by Mario Braw

The Journal of the Department of Agriculture
OF PORTO RICO

Published Quarterly: January, April, July and October of each year.

VOL. X JULY AND OCTOBER 1926 NOS. 3 AND 4

THE EYE-SPOT DISEASE OF SUGAR CANE

MELVILLE T. COOK, Chief of Division of Plant Pathology

The eye-spot disease of sugar cane became serious in Porto Rico in 1922–23. Like most diseases which suddenly appear as menace to a crop it was referred to by the growers as a new and mysterious disease and was given several local names. Along the north coast it was frequently referred to as the Manatí disease because it was first found n the vicinity of Manatí. Along the south coast it was sometimes referred to as Santa Rita disease although that name was not used so extensively as Manatí. Fortunately these two names have gone out of use and the disease is now generally known as "eye spot", a name which is very generally used in other cane-growing regions of the world. The first studies made by the writer showed considerable variations in the spots and in size of the spores which led us to suspect that that spotting might be due to two-species of organism causing the disease but later studies have shown that this is not true.

Although the disease was at first referred to as new and mysterious, the studies made by the writer very soon showed that it is the common "eye spot" which is caused by a fungus (*Helminthosporium sacchari* Butler) and is well known in other parts of the world. It was first reported from Porto Rico by Johnston and Stevenson **(8)** in 1917, but it was no doubt present on the Island many years previous to that date. Its sudden appearance as a severe disease in Porto Rico was no doubt due to the growing of an increased acreage of susceptible varieties and to the climatic conditions in 1922–23 which were especially faborable to the growth of the fungus. In 1923–24 the disease was less severe, due to unfavorable conditions but it has been quite severe during the following years. The threatening character of this disease lead us to make studies which have been carried out during a period of four years and are recorded in this paper.

HISTORY

The prevalence, wide distribution and general character of this disease give ample reason for believing that it is very old although

we have no authentic records previous to 1892 when it was first reported and described from Java by L. van Breda de Haan **(5)** who demonstrated that it was infectious and due to a fungus which he named *Cercospora sacchari*. A more complete account of the disease and a colored plate was published from Java in 1898 by Wakker and Went **(18)**. In 1901 the disease was discussed in another publication from Java by Dickhoff and Hein.

In 1907 the disease was reported from Hawaii by Lewton-Brain **(15)** who stated that the disease had been known previously as "rust". In 1909 the disease was again reported from Hawaii by Cobb **(3)** who also published a colored plate which corresponds quite well to the disease as found in the greater part of Porto Rico, but his spore drawings are of *Helminthosporium*. In 1922 Larsen **(9)** reported the isolation of the fungus and the reproduction of the disease by spraying cane leaves with a spore infusion.

In 1913 it was reported and described from India by Butler **(2)** under the name of *Helminthosporium sacchari* who comments on previous work as follows:

> "In Hawaii it has been briefly described by Cobb. From the figures published in Wakker and Went's well-known textbook of sugar-cane diseases, it appears probable that this fungus is really a *Helminthosporium* and not a *Cercospora*. A comparison of the two fungi has not been possible and could alone settle the question of their identity."

Butler's nomenclature is very generally followed by mycologists and plant pathologists. Butler reported that the disease had "not been found to damage the crop materially".

The disease was first reported from Porto Rico in 1917 by Johnston and Stevenson **(8)** who evidently did not consider it of much importance. It was next reported from Porto Rico by the writer **(4)** in 1924 in a preliminary paper as a disease which threatened to be of major importance.

The latest publication is a series of papers from Hawaii by Lee **(7, 10–14, 16, 17)** and others in which various phases of the disease and discussed. These publications will be referred to from time to times in this paper. In the first of this series Lee **(10)** calls attention to the fact that early publications indicate that the disease probably existed in Hawaii as early as 1854, that it was considered as serious and was known as "fire blight". This is 39 years earlier than the first authentic record by van Breda de Haan.

Although there is reason to believe that the disease is widely distributed throughout the sugar-cane-growing regions of the world the only reports of serious outbreaks are from Hawaii and Porto

Rico and the only important varieties that have proved, especially susceptible in Porto Rico, are D. 109 and F.C. 306. H. 109 has been introduced into Porto Rico but has not been grown extensively. It is less susceptible in Porto Rico than D. 109 and F.C. 306.

The preceding discussion includes references to the most important publications but there are many other brief references which show the wide distributions of the disease throughout the sugar-cane-growing countries of the world. These records show that the disease is known in Java, Hawaii, India, Philippines, Formosa, and Southern United States. It has been reported from West Indies, from Cuba, Jamaica, Santo Domingo, Barbados, Trinidad and Reunion.

SYMPTOMS

The eye spot is usually well defined and characteristic but is subject to many variations, depending on variety, age, severity of infection, climatic and possibly other factors. The disease occurs on the lower half of the blade, sometimes attacking the sheaths but rarely attacking the outer half of the leaf except in the case of young plants, when the entire leaf may be attacked.

The disease usually starts as very small reddish, occasionally black spots. If the variety is very resistant, this character may disappear with the growth of the plant. If the variety is susceptible, the spot increases in size and developes other colors. Most spots on susceptible varieties are red when young but usually develop black centers and yellowish borders. The arrangement of these colors and the elongated, pointed form have given rise to the common name "eye spot". However, the spots are not uniform in either shape or color. Any one of the colors may predominate. Sometimes the spot remains red until one-fourth inch in length before showing a black center. Sometimes the colors have rather definite outlines and sometimes they blend. Sometimes the spots have the definite eye form and at other times they take the form of long narrow black streaks of various lengths; usually one-fourth inch to 3 inches but occasionally more. Sometimes they are long, dark in color and of a rather irregular outline. Sometimes they unite, usually at the end. In young spots, the colors are usually bright and clear but as the spots grow old the colors become dull and almost disappear with the dying of the leaf. As the spots grow old, they usually develope ashy-colored centers as a result of a dying of the central tissues. In the case of the more susceptible varieties, such as F.C. 306 and D. 109, the entire leaf may dry, and in the case of severe outbreaks it is not uncommon for three-fourth or more of the leaves to

be killed. Entire fields become brown, except for a few green leaves at the tops of the plants. The spots may occur on any part of the lower half of the leaf from midrib to margin but do not occur on the midrib. In the case of severely infected young plants and seedlings the entire plant may be varying shades of red, the tips and outer leaves die and become brown very soon and in many cases the plant is killed. In some cases the spots are blunt, with a predominance of red and purple colors which darken with age. Sometimes the spots coalesce, become irregular and develop into blotches which may enclose small areas of apparently healthy green issues. The margins of these blotches are frequently yellow. These blotch characteristics were originally attributed to the so-called "Santa Rita" disease, but a more extensive study indicates that we have but the one species of the fungus. Therefore, the blotching must be considered one of the variations of the disease symptoms. Although the characteristic blotchings are most common on the south coast, they do occur in other parts of the Island and the writer has produced them under green-house conditions by heavy infection of the young canes. The top-rot symptom which is described in publications from Hawaii is rare in Porto Rico but the "fire blight" which is also described in the Hawaiian publications is quite common, especially on D. 109 when grown on the higher elevations. Many of these variations are no doubt due to varieties and to climatic conditions, but some of them may be due to soil conditions as previously referred to by the writer **(4)** or to the presence of other fungi which are more or less common on the spots.

The disease attacks the lower half of young leaves of growing cane while they are unrolling. The spores are apparently carried by the wind and fall into the tops of the cane, and since the arrangement of the leaves is especially favorable for the collection of moisture, the conditions are most favorable for the growth of the fungus.

The *ring spot* of sugar cane is due to an entirely different fungus (*Leptosphaeria sacchari* J. van Breda de Haan). It is possible that this disease might be confused with the "eye spot" by inexperienced observers, but a little study will enable any one to distiguish the two diseases in most cases. This spot occurs on the outer half of the older leaves. The spots are much broader and shorter than the eye spots and are usually not more than two or three times as long as wide, more or less irregular in outline, and tending to unite, so that in many cases the outer-one-fourth or one-half of the old leaves are entirely dead. The ring spots are brownish or reddish but the colors are never so bright as in the eye spots. Gray dead centers develope

very early so that in a very short time the spots show as large gray areas surrounded by a narrow zone of brown, black or reddish tissue.

LOSSES

It is extremely difficult to estimate the losses due to a disease of this type with any degree of accuracy, but it is very evident that the losses must be considerable in the cases of the severe outbreaks. Since the greater part of the manufacture of sugar is in the leaves of the plant, the destruction of any considerable part of the leaf must necessarily reduce the working power of the plant proportionately. And since the disease attacks the leaf so early in its development, the areas that are destroyed have practically no part in the manufacture of sugar or in furnishing elaborated foods for the growth of the plant. Therefore, the greater the destruction of the leaf tissue, the greater the reduction in growth and manufacture of sugar. The writer has seen very large areas of B. 109 and F.C. 306 in which 80 per cent of the leaves were entirely dead long before maturity. Furthermore, the disease frequently kills canes varying in height from a few inches to four feet. In one field of F.C. 306, fifty-seven per cent of the canes were killed. In the case of very susceptible varieties, many young canes of ratoon growths are killed. Seedlings are frequently destroyed in great numbers. The writer has seen outbreaks in the seedling flats which resulted in the death of many hundred seedlings, and Mr. Robert L. Davis of the Porto Rico Agricultural Experiment Station writes that in the case of one variety "only 250 out of 1,106 survided". When young canes are killed, they are very frequently attacked by the rind disease (*Melanconium sacchari* Massaee) which finishes the work of destruction, although it is primarily a saprophyte.

THE ORGANISM

The organism was described by Butler **(2)** from India in 1913 as follows:

"The infected leaves first show small red spots, which spread rapidly, chiefly in the longitudinal direction and, especially towards the tip of the leaf, may run together to form long streaks. The center of the spot soon changes to a dirty straw color, around which the margin remains red for a time and then changes to dark brown. The spots occur equally on the midrib, where they may be confused with those caused by the leaf form of *Colletotricum falcatum* and on the thinner part of the leaf. When numerous, they cause death of the leaf tissues beyond the limits of the spots; the tip of the leaf often withers completely and there are many long withered strips down the margins.

"The sporophores are stout, erect, rather rigid hyphae, which arise from the peripheral cells of the stromata (Pl. VI, Fig. 4). They are usually unbranched,

3 to 10 septate, dark greenish-brown below, paler above and several times bent or 'geniculate'. Spores are produced at each bend and at the apex, the lowest being due to the spores being always apical at first and being then pushed to one side by continued growth of the sporophore from just below the insertion of the spore. The sporophores are 100 to 190 microns long, by 5.5 to 7.5 microns broad.

"The spores (Pl. VI, Fig. 5) are borne single and readily fall off. They are cylindrical or long elliptical in shape, with very thick walls, and divided into from 4 to 11 compartments by broad thick partitions. The colour varies from olive green to brown and the size from 35 to 60 microns long, by 8.5 to 12 microns broad.

"*Helminthosporium sacchari* Butl. n. sp. Maculis amphigenis, elongatis, initio, rubris, dein avellaneis, vel stramineis ac ferrugineo-marginatis, 3–25 × 2–6 mm.; caespitulis minutis, atris; hyphis fertilbus erectis simplicibus, 3–10—septatis, geniculatis, olivaceo-brunneis, apice pallidioribus, 100–190 × 5.5–7.5 microns; conidiis acrogenis, cylindraceis vel oblongo-ellipticis, utrinque rotundatis, 3–10 septatis, carssissime tunicatis, olivaceo-brunnels, 35–60 × 9.5–12 microns."

The description given by Johnston and Stevenson reads as follows:

"Hyphae dark, cobwebby, arising from the center of an elongated brown spot on the leaf-blade; sporophores more or less erect with single terminal spores; spores several septate with very thick walls, rounded at both ends, 32–90 × 9–14 microms, on conidiophores 120–160 mm. long."

The writer measured several hundred spores (Fig. 1) the minimum being 22 × 6.6 u while the maximums were 92 × 13 u and 88 × 15 u. The average was 58.7 × 11.1. The septa ranged from 3 to 11. The minimum sporophore (Fig. 2) was 44 u while the maximum was 337.5 u. These measurements were made from spores and sporophores from leaves of 23 varieties of cane which had been in moist chamber 24 hours. It was impossible to correlate the measurements with the varieties of cane.

The size of the spores appear to depend primarily on humidity. Both in the field and laboratory, under dry conditions, the spores were few and large while under moist conditions they were many and small. However, in the laboratory the spores formed in moist chamber during the first 24 hours were usually larger than those for any succeeding 24 hours.

The young sporophores are more or less straight and the spores are borne apically. Possibly it would be better to say that the youngest spore is borne apically. Following the formation of the first spore, there is a new growth starting just back of the point of attachment which extends forward and at a slight angle. A new spore is formed at the tip of the new growth and another new growth is started. This occurs repeatedly and results in a geniculate spo-

rophore with scars at the angles. The attachment of the spores is so delicate that very few are seen in place.

LABORATORY STUDIES

The spores are very brittle and fall from the sporophore very readily. Therefore, it is difficult to find them on leaves fresh from the field unless the leaves are collected early in the morning and handled carefully. However, they can be secured in great abundance on leaves kept in a moist chamber for 24 hours. However, the spores produced each succeeding 24 hours are likely to be smaller than the preceding. Furthermore, the spores grown in culture are very generally smaller than those found in nature. The spores are borne more abundantly on the lower than on the upper surface of the leaf. The sporophores vary greatly not only in size but also in each group or cluster. When single they were usually longer and more spores are produced than when in groups. They are geniculate, a single spore being produced from the convex side of the bend or angle. The spores originate from the apex, a new growth starts just below the spore and is forced slightly to one side, causing the first bend. This is repeated and results in alternate right and left bends.

The spores germinate very freely in water (Fig. 4) usually with a single tube and usually from one end of a spore. If grown on a piece of glass, the tube twists around and grows in various directions (Fig. 6) but if grown on the leaf it advances but a short distance and then penetrates at a point between the veins or fibro-vascular bundles without regard to the presence or absence of stomata (Figs. 7 and 10). Spores will germinate on and penetrate either surface of the leaf, but inoculation experiments have shown that the upper surface is more susceptible than the lower surface. This was demonstrated by applying agar containing spores at various points along the surfaces of the leaf or along the entire surface. This film of agar was removed after 48 hours. These experiments were repeated a number of times, and the plants kept in a greenhouse. The spots were always more numerous on the upper than on the lower surface. Very young leaves are susceptible from base to tip on both surfaces, but as they grow older they gradually loose their susceptibility, beginning with the tip; the upper surface remaining susceptible longer than the lower surface. The upper surface of a reasonably young leaf is susceptible nearer the tip than the under surface of the same leaf. The sporophores will also germinate and are probably as important in spreading the disease as the spores.

The penetration of the leaf by the germ tube is very quickly followed by a discoloration and formation of a spot (Figs. 7 to 10). In some cases the spot can be detected by the unaided eye within 30 hours after inoculation. This spot increases in size, the greater growth being lengthwise and between the larger fibro-vascular bundles. It appears to be rather difficult for the fungus to penetrate the fibro-vascular bundles, although this does occur.

The germ tube appears to be able to penetrate at any point between the fibro-vascular bundles or veins. It was not seen to penetrate immediately over or under a fibro-vascular bundle, nor into a stomata. The first growth of the mycellium after penetration is in the parenchyma tissues and is either inter- or intra-cellular (Fig. 12) and the septa are comparatively few. The spots increase in size, especially in length with age, the discolorations usually extending beyond the range of the fungus. The mycelium becomes more and more abundant and the septa more numerous. It frequently acquires the power to penetrate the fibro-vascular bundles (Figs. 13 to 15), but age and the resistance of the hard walls of the cells of the fibro-vascular bundles results in the formation of masses of fungus cells resembling sclerotia, usually just within the epidermis and next to the fibro-vascular bundles (Figs. 9 and 11). The resistance exerted by the hard cell walls of the fibro-vascular bundles appear to be the stimulus which leads to the formation of septa and the sclerotia-like growth. This growth breaks, through the epidermis and forms sporophores. It also frequently produces a growth which spreads over small areas of the surface of the leaf (Fig. 11). The sporophores were also seen growing out through stomata.

A careful study was made of the structure of the leaves of a large number of varieties and a comparison of the most resistant with most susceptible varieties indicated that the varieties with numerous, close fibro-vascular bundles were more resistant than the varieties in which the fibro-vascular bundles were rather widely separated by large quantities of parenchyma tissue. This is in harmony with the large amount of mycelium in the parenchyma as compared with the fibro-vascular bundles.

INOCULATION EXPERIMENTS

The inoculations were made in both greenhouse and field for the purpose of determining the relative susceptibility of the many varieties. Inoculations are easily made either by the use of spore infusions applied with an atomizer or by pouring the infusion into the tops of the cane plants. The simplest and easiest method, was the

application in the top of the cane by means of a glass tube. When the spore infusions are applied to the base of the young leaves, infections can be obtained in very nearly 100 per cent of the cases, but if applied to the old leaves or tips of leaves the results are usually negative. The best time for inoculation is late in the afternoon, probably because the plants retain the moisture during the night better than under the bright sunshine of the day. It is not necessary to injure the surface of the leaf. Infections may be obtained at any season of the year but the plants respond more readily during the cooler months of November, December, January and February and March, which is the season the disease is most abundant in the fields. During the warm, summer months, infections are easily obtained, but under conditions here at the Insular Experiment Station there is very little spread of the disease from the infected to the neighboring plants. All varieties can be infected, but in the most resistant varieties the spots can not be seen without close study. Uba may be considered most resistant, and close examinations made 48 hours after inoculation showed minute black spots. Varieties do not always respond in the same manner even though the experiments are made in the same place and as nearly as possible under the same conditions. This is well shown in the following tables:

TABLE I

GREENHOUSE INOCULATION

The groups are arranged in order of susceptibility, the most susceptible first

D. 433	F.C. 214
F.C. 306	S.C. 12(4)
D. 109	B.H. 10(12)
P.R. 460	P.R. 328
B.H. 10(12)	P.R. 329
	B. 3412
B. 67	H. 109
D. 109	D. 1135
Ba. 11569	P.R. 492
P.R. 433	P.R. 440
B. 6450	Cristalina
D. 109	P.R. 333
P.R. 729	Uba
Ba. 6032	Badila
D. 448	P.O.J. 105

TABLE II

GREENHOUSE INOCULATION

The groups are arranged in order of susceptibility, the most susceptible first

F.C. 306	P.R. 440
D. 109	P.R. 328
	P.R. 492
H. 109	Yellow Caledonia
P.R. 433	B. 67
Ba. 11569	P.O.J. 105
D. 448	P.R. 440
D. 109	
	B.H. 10(12)
Ba. 6032	S.C. 12(4)
P.R. 329	Cristalina
F.C. 214	B. 3412
	P.R. 333
D. 1135	Badila
B.H. 10(12)	Uba

In Table I it will noted D–109 was used in three and B.H. 10(12) in two different containers with different results, although the containers were separated by spaces of less than 10 feet.

It will also be noted that the results in the two tables are slightly different. This is especially true in the case of B. 67. However, F.C. 306 and D. 109 can be depended on as very generally showing the greatest susceptibility.

TABLE III

PLANTS KILLED IN GREENHOUSE AS RESULT OF HEAVY INFECTION

These plants were grown in 5-gallon oil cans and four buds planted in each can.

	First record	Second record	Third record
D. 117	all	—	—
Cristalina	5	1	1
Ba. 6032	1	2	all
D. 448	2	—	all
D. 433	1	—	—
B.H. 10(12)	—	4	—
B. 6450	—	1	2
P.R. 711	—	1	1
Badila	—	1	—
Ba. 11569	—	1	—
F.C. 306	—	1	—
P.R. 328	—	1	—
B. 3412	—	1	1
H. 109	—	1	—
P.R. 460	—	—	2
P.R. 433	—	—	1
P.R. 704	—	—	1
P.R. 440	—	—	1

In comparing the results given in Table III with the results of Tables I and II it will be readily seen that the varieties showing the greatest leaf infection in Tables I and II did not show the highest mortality. However, the number of plants used in Table III was so small that no definite conclusions can be drawn from this experiment. Furthermore, the field observations showed a greater mortality in FC–306 than in any other variety.

TABLE IV

INOCULATION MADE ON PLOT WITH OVERHEAD IRRIGATION

Records made every week for six weeks

xxxxx = very severe; xxxx = severe; xxx = medium; xx = slight; x = very slight

Rank	Variety	First record	Second record	Third record	Fourth record	Fifth record	Sixth record
1.	F.C. 306	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx
2.	D. 109	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx
3.	H. 109	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx
4.	P.R. 433	xxx	xxxx	xxxx	xxxx	xxxx	xxxx
5.	P.R. 460	-----	xxxx	xxxx	xxxx	xxxx	xxxx
6.	P.R. 328	xx	xxx	xxx	xxx	xxx	xxxx
7.	B. 3412	xxx	xxx	xxx	xxx	xxx	xxx
8.	P.R. 440	x	xxx	xxx	xxx	xxx	xxx
9.	B.H. 10(12)	-----	xx	xx	xx	xxx	xxx
10.	B. 6450	-----	-----	-----	-----	xxx	xxx
11.	P.R. 792	x	xx	xx	xx	xxx	xxx
12.	P.R. 329	x	xx	xx	xx	xx	xx
13.	F.C. 214	xx	xx	xx	xx	xx	xx
14.	D. 433	x	x	x	x	x	x
15.	B. 67	-----	-----	-----	-----	xxxxx	xxxxx
16.	Cristalina	-----	-----	-----	-----	xxxxx	xxxxx
17.	P.R. 726	-----	-----	-----	-----	xxx	xxx
18.	Ba. 6032	-----	-----	-----	-----	xxx	xxx
19.	Ba. 11569	-----	-----	-----	-----	xx	xx
20.	Badila	-----	-----	-----	-----	xx	xx
21.	D. 448	-----	-----	-----	-----	-----	x
22.	D. 1135	-----	-----	-----	-----	-----	-----
	P.R. 492	-----	-----	-----	-----	-----	-----
	D. 117	-----	-----	-----	-----	-----	-----
23.	Uba	-----	-----	-----	-----	-----	-----

Tables V, VI and VII are made from a field at the entrance of the Insular Experiment Station. The land is low, the humidity high and the temperature favorable during the winter months. The disease appeared here in advance of any other place on the Insular Experiment Station and was more severe.

TABLE V

xxxxx = very severe; xxxx = severe; xxx = medium; xx = slight; x = very slight

Rank	Variety	First record	Second record	Third record
1.	F.C. 306	xxxxx	xxxxx	xxxxx
2.	D. 109	xxxx	xxxx	xxxx
3.	P.R. 329	xxxx	xxxx	xxxx
4.	B. 3412	xxxx	xxxx	xxxx
5.	D. 448	xxxx	xxxx	xxxx
6.	F.C. 214	xxx	xxx	xxxx
7.	D. 433	xxx	xxx	xxxx
8.	B.H. 10(12)	xxxx	xxx	xxx
9.	H. 109	xxx	xxx	xxx
10.	P.O.J. 36	xxx	xxx	xxx
11.	M. 36	xxx	xxx	xxx
12.	P.R. 440	xxx	xxx	xxx
13.	Cristalina	xx	xx	xxx
14.	Yellow Caledonia	xxx	xx	x
15.	D. 1135	xx	xx	xx
16.	P.R. 492	xx	xx	xx
17.	P.O.J. 228	xxxxx	-----	-----
18.	Ba. 6032	xxxx	x	-----
19.	P.R. 460	xxx	x	-----
20.	D. 117	xxx	x	-----
21.	B. 67	xx	x	-----
22.	P.R. 328	xx	x	-----
23.	P.R. 729	xx	x	-----
24.	B. 6450	x	x	-----
25.	P.O.J. 234	xx	-----	-----
26.	Ba. 11569	xx	-----	-----
27.	S.C. 12(4)	xx	-----	-----
28.	Uba	-----	-----	-----

Table V is a composite made up from studies following inoculation. The first reading was made 4 days after inoculation and the second two months later and the third one month after the second.

A comparison of Tables IV and V shows that although F.C. 306 and D. 109 are the most susceptible and that Uba is the most resistant, the other varieties do not occupy the same positions in the two tests.

TABLE VI

NATURAL INFECTION IN THE SAME FIELD

December 8th, 1926

F.C. 306	xxxxx	P.O.J. 36	xx
Ba. 6032	xxxxx	D. 433	xx
		D. 1135	xx
D. 109	xxxx	P.R. 492	xx
P.R. 329	xxxx	P.R. 460	xx
F.C. 214	xxxx	B. 67	xx
D. 216	xxxx		
P.R. 328	xxxx	P.R. 729	x
H. 109	xxxx		
		P.O.J. 234	
B.H. 10(12)	xxx	P.O.J. 228	
M. 36	xxx	D. 117	
P.R. 440	xxx	Ba. 11569	
B. 6450	xxx	Uba	

TABLE VII

NATURAL INFECTION IN THE SAME FIELD

January 14th, 1927

F.C. 306	xxxxx	Cristalina	xx
D. 109	xxxxx	P.R. 729	xx
Ba. 6032	xxxxx	B.H. 10(12)	xx
Y. Caledonia	xxxxx	D. 433	xx
		D. 448	xx
H. 109	xxxx		
		P.R. 492	x
P.O.J. 36	xxx	P.R. 460	x
M. 36	xxx	B. 67	x
B. 3412	xxx	Ba. 11569	x
P.R. 440	xxx	B. 6450	x
P.R. 328	xxx		
P.R. 329	xxx	P.O.J. 228	trace
F.C. 214	xxx	P.O.J. 234	trace
		D. 1135	trace
		D. 117	trace
		Uba	0

A comparison of Tables V, VI and VII shows that although the varieties do not occupy exactly the same relative positions, F.C. 306 and D. 109 are most susceptible and that Uba is the most resistant.

TABLE VIII

This field was part of the property of Central Cambalache. It had been planted to varieties for the purpose of studying resistance of varieties to mosaic but became infected with *Helminthosporium sacchari*. This field is located on low land, near the coast.

Variety	Severity	Remarks
F.C. 306	xxxxx	
D. 109	xxxxx	
P.R. 329	xxxxx	
D. 448	xxxxx	
B. 3405	xxxxx	
B. 3412	xxxxx	
P.R. 662	xxxxx	
P.R. 433	xxxxx	Very few living leaves.
B. 67	xxxxx	Leaves yellow, long narrow streaks.
Rayada	xxxxx	Apparently less damage than on others.
H. 109	xxxx	
D. 625	xxx	
B. 208	xxx	
P.R. 545	xxx	No great damage.
S.C. 12(4)	xx	Many small spots. No great damage.
Ba. 11569	xx	Many small spots. No great damage.
P.R. 328	xx	
P.R. 414	xx	
P.R. 440	xx	
P.R. 561	xx	
D. 117	xx	Very small spots.
B. 3696	x	Very few small spots.
Cristalina	x	
L. 511	x	Very few spots.
P.R. 417		Occasional spot.
P.R. 492		Occasional spot.
P.R. 433		Occasional spot.
B.H. 10(12)		Occasional spot.
P.R. 260		Occasional spot.
Uba		Practically immune.

TABLE IX

In another record at a different date, from the same field; also a grouping with reference to age, purity and sucrose content of the varieties. The field data was taken by the writer. The information on age, purity and sucrose was furnished by Mr. Pedro Olivencia of Central Cambalache.

Variety	Severity	Remarks	Age in months	Purity	Sucrose
B. 3412	xxxxxx	Most severe of all	12	86.37	15.35
P.R. 433	xxxxx	Most leaves die	11	91.19	16.87
B. 67	xxxxx	Most leaves very yellow	12	90.63	17.22
P.R. 329	xxxxx		12	88.70	15.79
P.R. 662	xxxxx		11	90.58	17.80
F.C. 306	xxxxx		12	79.01	13.54
B. 3405	xxxxx		12	80.70	12.28
Rayada	xxxxx		12	83.46	15.61
D. 448	xxxxx		12	90.40	19.12
P.R. 545	xx	No great damage	12	83.38	14.68
B. 208	xx		12	86.90	14.40
P.R. 440	xx	Many small spots	12	88.49	15.00
P.R. 561	xx	Many small spots	12	79.18	13.92
P.R. 414	xx		12	86.90	13.61
P.R. 328	xx	Many small spots	12	84.88	15.11
P.R. 569	xx	Very small spots	12	90.40	17.37
H. 109	xx	Many small spots	--	-----	15.51
S.C. 12(4)	xx	Many small spits	12	87.30	13.85
P.R. 412	x	Resistant, slight infection	12	72.08	12.63
Cristalina	x	Resistant, few small spots	11	89.22	15.48
D. 117	x	Resistant, many small spots	15	84.13	15.06
B. 3696	x	Resistant, very few small spots	12	88.24	15.31
L. 511	x	Very resistant	14	86.50	15.65
B.H. 10(12)	x	Very resistant	12	76.91	13.85
D. 433	x		15	81.29	14.49
P.R. 260		An occasional spot	12	86.02	15.70

A comparison of the Tables VIII and IX is not possible because they do not record exactly the same varieties but they do show somewhat the same relationship of hosts to the disease.

Table IX also shows a grouping with reference to purity and sucrose, but these figures are only approximately correct as other analyses where no field studies were made have given different results. These variations in purity and sucrose content are due to factors which do not come within the scope of this paper. They indicate that there may be some relationship between susceptibility and resistance to purity and sucrose content. However, it also appears that there are other factors, such as climatic conditions and structure which are more important.

VARIETAL SUSCEPTIBILITY AND RESISTANCE

A study of these tables and our notes on field observations shows very definitely that F.C. 306 is the most susceptible commercial variety grown in Porto Rico. D. 109 is a close second. H. 109 can be placed third in the list but is much more resistant than D. 109. Uba is the most resistant variety grown on the Island. The records on the other varieties show more or less variations but they can be grouped as follows:

F.C. 306
D. 109
H. 109

D. 433
P.R. 460
B.H. 10(12)
B. 6450
Ba. 6032
D. 448
F.C. 214
P.R. 329
Yellow Caledonia

B. 67
P.R. 729
P.R. 328
B. 3412

P.R. 440
D. 117

S.C. 12(4)
D. 1135
P.R. 492
P.R. 333
Cristalina
Badila

P.O.J. 105
P.O.J. 36
P.O.J. 228
P.O.J. 234
M. 36

Uba

In general it may be said that the disease is so severe on F.C. 306 and D. 109 under most conditions in Porto Rico and that we cannot recommend their use. H 109 is more resistant but cannot be recommended. B.H. 10(12) and S.C. 12(4) which may be looked upon as the leading varieties in Porto Rico at this time are fairly resistant under most conditions in Porto Rco, but the writer has seen several severe outbreaks of the disease on B.H. 10(12) and a few severe attacks on S.C. 12(4). Although Uba is so resistant that for a time the writer considered it practically immune, one field was found in which this variety was heavily infected and a few fields in which there was a slight infection.

A comparative study of the structure of the leaves of a large number of varieties was made and it was found that resistance was correlated to a greater of less degree with structure, although this may not be the only factor involved. Varieties in which the fibro vascular bundles of the leaves were closely placed were more resistant than those varieties in which they were widely separated by parenchyma tissue. This is in harmony with the fact that the fungus

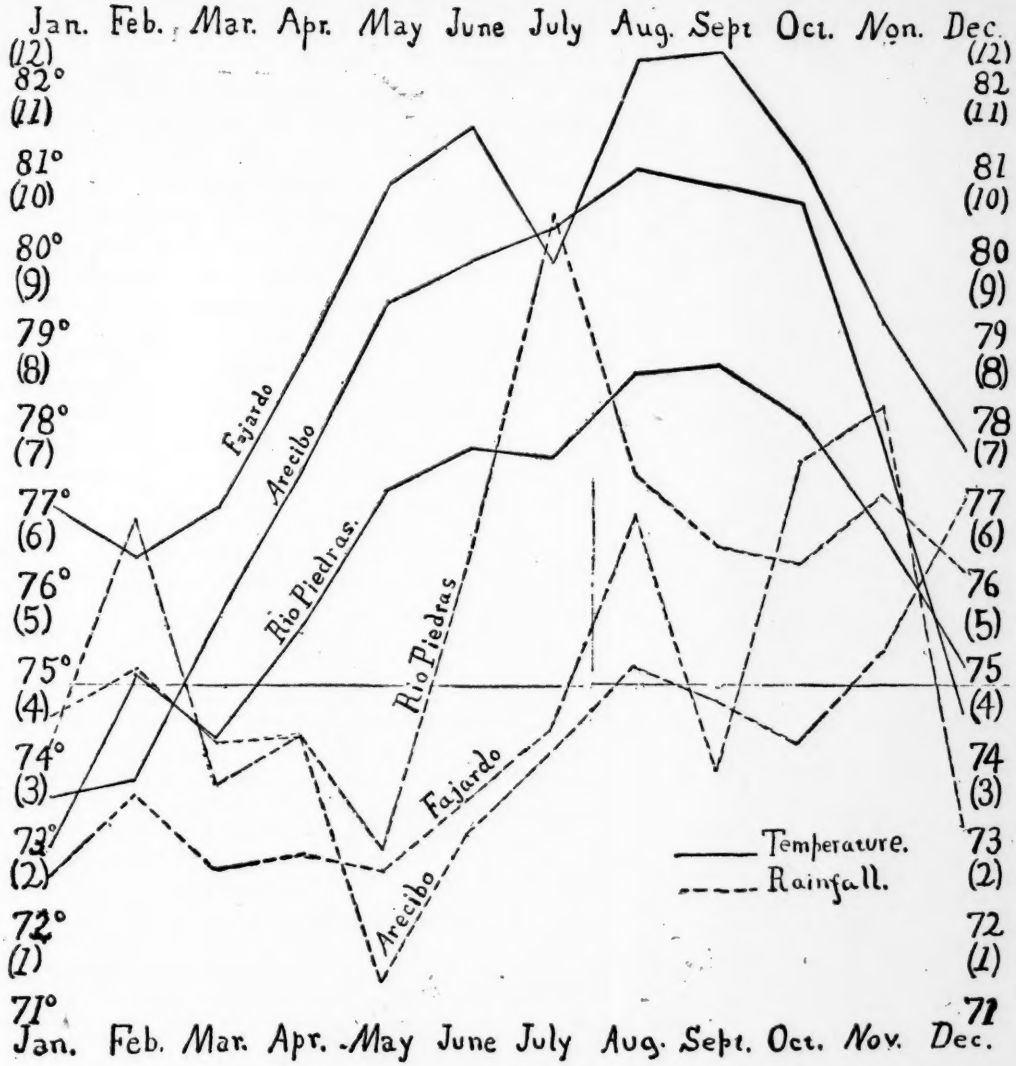


TABLE X

A chart showing temperature and rainfall, based on figures given in Table XI. The temperature indicated in degrees F. The rainfall in inches by the figures in parentheses.

penetrates between the veins of the leaf and makes its first growth and in fact most of its growth in the parenchyma tissue.

A limited study was made of the roots but no injuries were traced to *H. sacchari*. Cultures of the organism were applied to the roots of growing cane in the greenhouse but we failed to find any evidence that the organism attacks the roots.

CLIMATIC FACTORS

Very early in our studies on this disease, it became evident that there were three very important factors in its severity: variety, temperature and moisture. The question of variety has already received consideration in the preceding pages.

Although the disease is much more severe in Porto Rico during the winter than during the summer months, it can be found at all times during the year. Fortunately, the U. S. Weather Bureau has excellent rainfall and temperature records for the three points where we made our studies. Tables X and XI are made from these records and is an average for 1922 to 1926 inclusive (except for the temperature record at Río Piedras which covers only three years). Hydrographs were placed at two points on the property of Central Cambalache; one near the coast where the records contained in Tables VIII and IX were made and the other in the hills. The later instrument was removed to the Granja and was broken by the wind storm that swept over the Island July 23rd, 1926. We have no records of value from this instrument. Two instruments were placed on the property of the Fajardo Sugar Co.; one in the locality of high humidity and the other in a locality of low humidity, a hydrothermograph was placed in the field on the Insular Experimental Station Farm from which the records of Tables V, VI and VII were made. All these records have been of value in our studies, but the hydrograph records have not been satisfactory as we had hoped for when the work was started.

TABLE XI

SHOWING AVERAGE RAINFALL AND TEMPERATURE OVER FIVE YEARS (1922–26)

Except for Río Piedras, where the temperature covers three years only

AVERAGE RAINFALL

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Río Piedras	4.65	5.17	4.35	4.44	3.10	6.55	10.56	7.50	6.63	6.44	7.26	6.35
Arecibo	4.24	6.94	3.88	4.40	1.50	3.24	4.21	5.20	4.82	4.33	5.38	7.22
Fajardo	2.75	3.71	2.84	3.01	2.83	3.68	4.48	6.99	4.07	7.65	8.29	3.33

AVERAGE TEMPERATURE

Río Piedras	73.1	75.1	74.4	75.7	77.3	77.8	77.7	78.7	78.8	78.2	76.8	75.2
Arecibo	73.7	73.9	75.8	77.6	79.5	80.0	80.4	81.1	80.9	79.7	77.9	74.7
Fajardo	77.1	76.5	77.1	78.9	80.9	81.6	82.0	82.4	82.3	81.2	79.3	77.8

The compilations from the U. S. Weather Bureau records (Tables X and XI) show a gradual decline in temperature from September to January and then a gradual rise until June. The coolest months are November to February inclusive and the warmest months are May to October inclusive. Of course the temperature was slightly lower during the night and somewhat higher during the day than is shown on the chart. The disease is most severe during November, December, January and February, and March the period of lowest temperature. The average rainfall for the same period is also shown on this chart. It will be readily seen that the greatest rainfall with one exception coincides fairly well with the period of low temperature. Our studies indicate that a low temperature and a high atmospheric humidity are most favorable for the development of this disease but it is very evident that the disease is more sensitive to variations in temperature than to variations in rainfall.

The thermograph records at Río Piedras showed the lowest temperature during the winter months and the highest during the summer, the most noticeable being about November 1st which was also the date of a rapid increase in the eye spot. The hydrograph showed a higher humidity during the summer months than during the winter months.

The hydrograph at Arecibo was placed near the ocean, where it was under the influence of a wind current from the ocean practically all the time, and showed a slightly higher humidity during the summer months. This is in harmony with the rain fall records although the ranges at Arecibo are not so pronounced as at other points. The average temperature records are lowest from December to March inclusive, the period of greatest severity for the disease.

At Fajardo, the range of lowest rainfall according to the U. S. Weather Bureau reports was from December to June inclusive and the lowest temperature from December to March inclusive, which was also the period of greatest severity for the disease. However, there was one record at Fajardo that was especially interesting. At one point (Paraiso) the rainfall ranged from 1.20 inches in March to 3.20 inches in October greater than the average for nine years for the Central zone. The disease was always more severe at this point than at two other points (Fortuna Centron and Santa Rita) where the local rainfall coincided quite well with the average for the Central zone.

However, a paper on "Relation of Temperature to the Growth of the Eye Spot Fungus" by Halma and Fawcett **(6)** was published in Phytopathology, August 1925, which has been valuable to us in

our work; according to the studies of these workers the fungus makes its most rapid growth under laboratory conditions at about 84° F. It grows more slowly at both higher and lower temperatures, making no growth at temperatures above 95 and very slow growth at 56 degrees.

We do not have the equipment for extensive experiments on either temperatures or humidity, but the results obtained with the one thermograph here at the Experiment Station and a study of the disease in connection with the U. S. Weather Bureau records indicate that the organism makes its best growth with an average outdoor temperature ranging from 73 to 77 degrees F. which is lower than the optimium temperature in the laboratory experiments with the organism in Hawaii. Of course it must be remembered that Weather Bureau records are not made in cane fields and that temperatures vary with local conditions and character of plant growths within short ranges of distance.

We have not done any experimental work for the control of this disease. The F.C. 306 and D. 109 which are our most susceptible varieties are gradually giving way to the more desirabe canes, such as B.H. 10(12) and S.C. 12(4) which are much more resistant to the disease and this is solving our problem of control at this time. The future development or introduction of more valuable canes which are susceptible to the disease may force studies for the control of the disease in the future.

SUMMARY

1. The "eye spot" disease which is caused by *Helminthosporium sacchari* Butler is serious on certain varieties of sugar cane in Porto Rico.

2. It is most severe on F.C. 306 and D. 109 with H. 109 as a poor third. The Uba and P.O.J. canes are most resistant.

3. The susceptibility varies with leaf structure, the higher the fiber content the greater the resistance. However, there appears to be some slight correlation with sucrose content.

4. The young leaves are more susceptible than the old leaves; the bases and upper surfaces more susceptible than the tips and lower surfaces.

5. The spores and sporophores germinate readily in water and penetrate the leaf without regard to the stomata. The greatest mycelial growth is in the parenchyma tissues. The spores are borne more abundantly on the lower than on the upper surface of the leaf.

6. The disease is most severe during the cool, wet months of the

year. Temperature appears to be the most important environmental factor.

7. The most satisfactory control for Porto Rico at his time consists in the use of resistant varieties.

The writer wishes to express his thanks to the Hon. C. E. Chardón, Commissioner of Agriculture of Porto Rico; Mr. Rafael Menéndez, Director of the Insular Experiment Station at the time the work was started; Mr. F. A. López Domínguez, present Director of the Insular Experiment Station; Dr. O. L. Fassig of the U. S. Weather Bureau in San Juan; Mr. R. A. Veve of the Fajardo Sugar Company; Mr. Pedro Olivencia of the Cambalache Sugar Company and many others for their assistance in this work.

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EXPLANATION OF PLATES

Fig. 1.—Spores of *Helminthosporium sacchari*, showing a variety of sizes and variation.
Fig. 2.—Sporophores of *H. sacchari*, showing variations.
Fig. 3.—Sporophore and spore.
Fig. 4.—Germination of spores.
Fig. 5.—Germination of sporophore.
Fig. 6.—A spore germinating on a glass slide.
Fig. 7.—Germinating spores on leaf of sugar cane. No discolorations.
Figs. 8 *a* and *b*.—Germinating sporophores on cane leaves. *a* shows the first trace of the formation of a spot. In *b* shows the dotted line indicates the size of the spot which lies between two fibro-vascular bundles.
Fig. 9.—A diagram of the lower margin of the leaf showing mycelium masses on the surface and also next to the fibro-vascular bundle. (Cross section.)
Fig. 10.—A germination spore on a leaf. One branch of the germ tube has penetrated the leaf and a spot is forming.
Fig. 11.—Showing the massing of the fungus near the lower surface of the leaf, the breaking through the epidermis, the growth on the surface and the formation of the sporophores. (See fig. 9).
Fig. 12.—The inter and intra-cellular growth of the mycellium.
Figs. 13–15.—The growth of the fungus in the cells. The large circles in 14 and 15 are tracheary tubes.

PLATE I

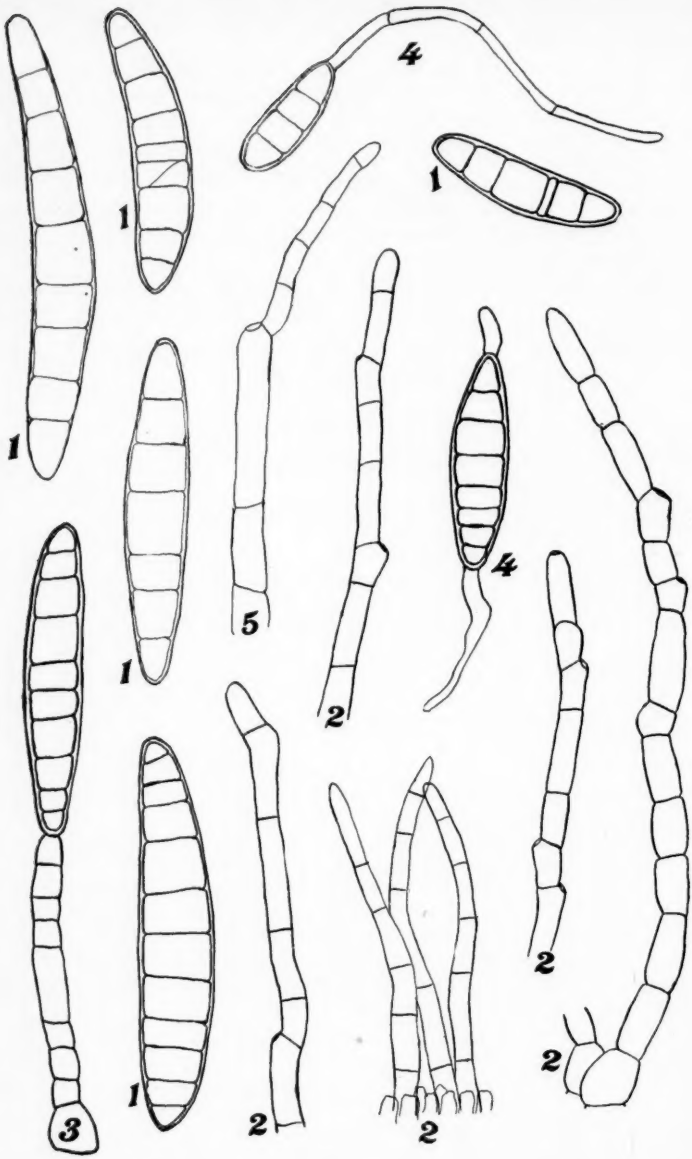


PLATE II

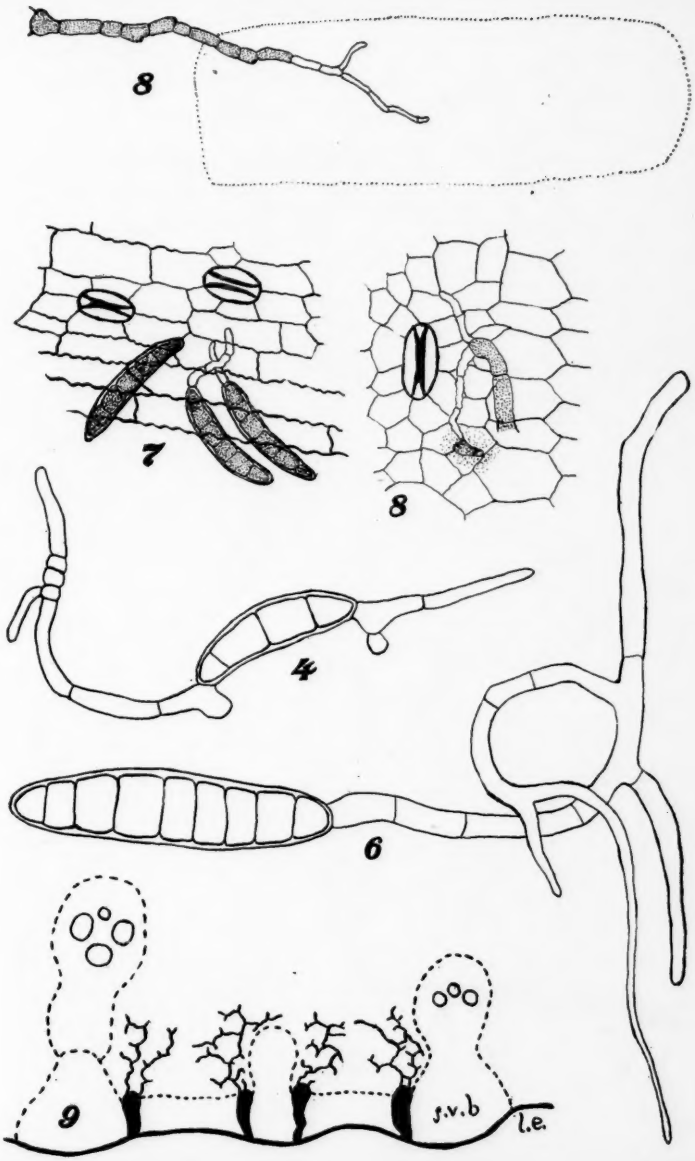
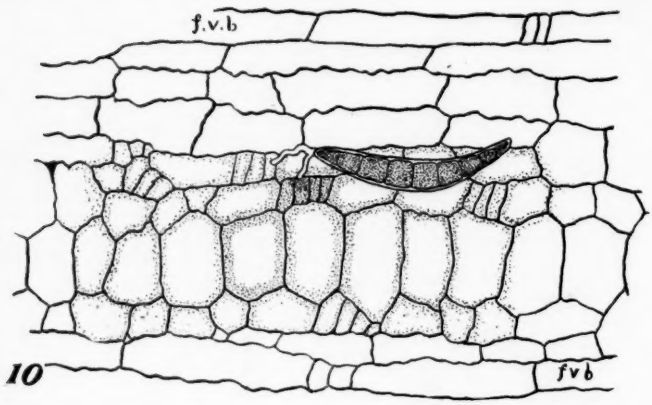


PLATE III



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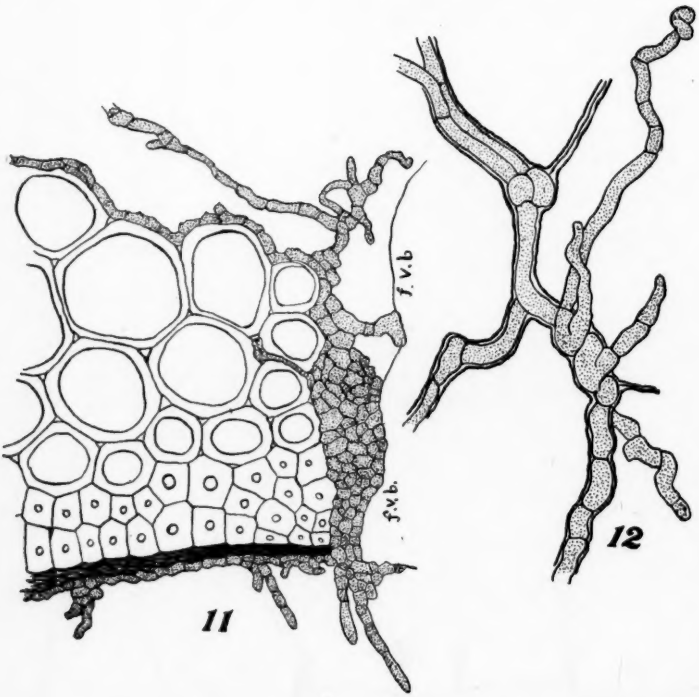

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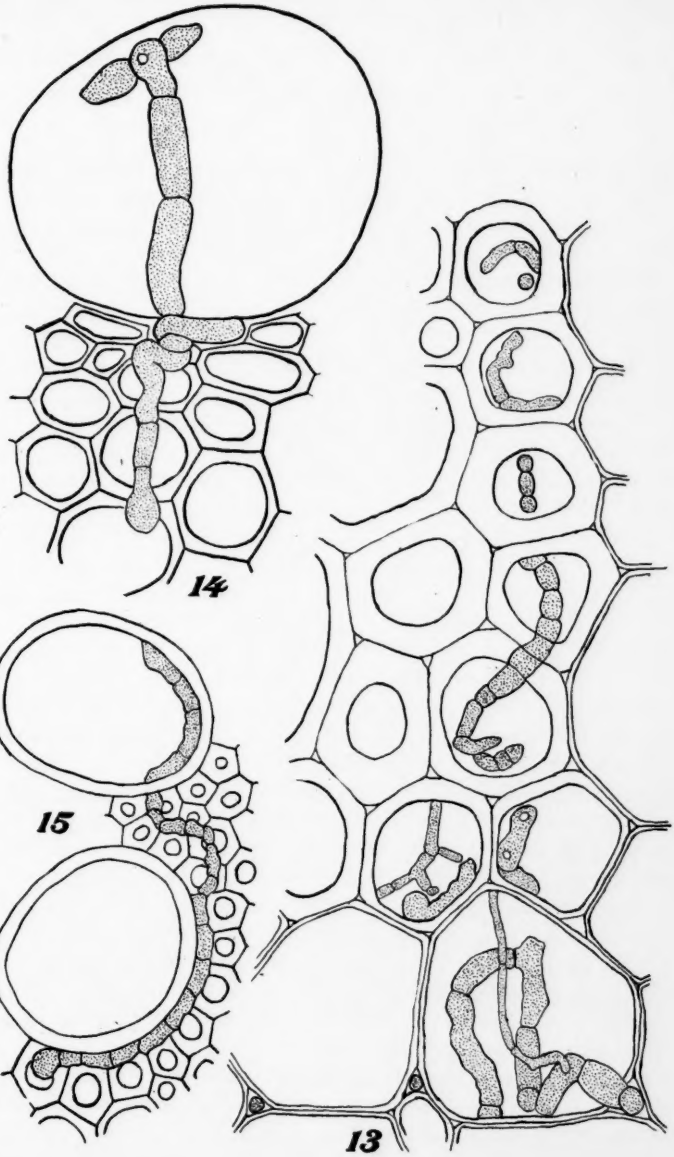
PLATE IV



THE EFFECT OF MOSAIC ON THE CONTENT OF THE PLANT CELL

MELVILLE T. COOK, Chief of the Division of Plant Pathology

This paper is a report on a continuation of the studies on the cytology of mosaic plants. The studies in the first paper **(1)** were restricted to sugar cane, but the studies discussed in this paper were extended to include tobacco for the purposes of comparison. The greater part of this paper will be devoted to the chloroplasts, but some attention will be given to the mosaic patterns on the leaves and to other points.

The writer has already called attention to certain differences in the cells from old and young leaves of a cane plant infected with mosaic **(1)**. It will be readily seen that the outside leaves of a sugar-cane plant are not only older than the inside leaves but that they have been subjected to the influence of sunlight and other external agencies for a much longer time; and it is well known that the older leaves of sugar cane and tobacco plants which are infected with mosaic, tend to lose their chlorotic character and become green after long exposure to sunlight.

In making these studies two plants of the same variety and age, one apparently healthy and the other infected with mosaic, were selected. Small pieces of tissue from corresponding parts of corresponding leaves were killed and fixed in weak Flemming solution, embedded in paraffine and stained by the triple-stain method. In the case of the diseased plant, the pieces were cut from both chlorotic and green areas and kept separate. This work was repeated several times but the drawings were made from two cane and two tobacco plants. In some cases plants with as many as thirteen leaves were selected while in other cases plants with as few as five leaves were selected. Sections were also made from the inner rolled leaves of the cane which had not been exposed to the direct action of the sun and in which it was impossible to distinguish the chlorotic areas.

Sugar cane and tobacco were selected for this work partly because they are important crops in Porto Rico and partly because they are so widely separated in the plant kingdom; one being monocotyledonous and the other dicotyledonous. In the sugar cane the leaves are rolled so that the young leaves are protected from the sunlight by the old leaves for a long time, while in the case of

the tobacco the leaves are exposed to the direct action of the sun when very young. This is a very important point in making the comparison because of the fact that the sunlight appears to have some effect on the chloroplasts of the chlorotic cells.

Before entering into the discussion of the effect of mosaic on the contents of the cell we will briefly review a few of the well-known facts concerning the effects of mosaic on the plants. It is well known that when plants are severely infected with mosaic, they are usually dwarfed; that the leaves of mosaic tobacco plants are smaller than leaves of normal plants; that in the case of many species, the chlorotic areas of leaves of mosaic plants are slightly thinner than the leaves of healthy plants; in the case of tobacco and many other plants there is a decided modification of the leaf tissues of mosaic plants in that the palisade is replaced by mesophyll and that the mesophyll in general becomes more compact than the mesophyll of an apparently healthy leaf. The meager statements concerning cell contents are indefinite and contradictory. Thus far the writer has been unable to detect any differences between the tissues from green areas of mosaic plants and the tissues from apparently healthy plants. Therefore, for the sake of brevity, we will always refer to the green or normal in comparison with the chlorotic or diseased areas.

In general it may be said that the action of sunlight on diseased plants tends to reduce the symptoms of the disease so far as color is concerned. This has been noted by the other workers and the writer has made a careful study of this point on the two plants under consideration. In both cases leaves that are very chlorotic when young tend to become green with age. In fact this is so pronounced that in some cases it is almost impossible to select chlorotic areas in old leaves with any degrees of certainty. It is also true that the sunlight or some other factor tends to bring the choroplasts of cells in chlorotic areas to normal in appearance.

These studies have shown that in the chlorotic areas in leaves of sugar cane, the most striking cytological characters are the reduction of the chloroplasts in size and number, usually accompanied by an enlargement and deformity of the nuclei and occasionally by the presence of intra-cellular bodies. In the case of tobacco the chloroplasts respond to the disease the same as in the sugar cane but there is no such marked modification of the nuclei. However, the intra-cellular bodies are very frequent and readily detected.

The young leaves of the sugar cane before unrolling are uniformly white or nearly so, and it is impossible to say which areas are to be-

come green and which are to remain white or chlorotic until they have been exposed to the light; but a cytological study of these leaves show that certain groups of cells already possess certain characters of chlorotic areas of later periods. The young leaves of diseased tobacco are usually almost white but develope the mosaic pattern with age. A cytological study of these young leaves reveals groups of cells which show the effects of the disease before the leaves show the mosaic pattern.

Kunkel **(6)** as a result of his studies on sugar cane says:

"The pattern shown by the leaves of most plants afflicted with mosaic is already present when the young leaves unfold and begin to turn green. For this reason it is in most cases not possible to determine how the chlorotic areas arise. In the case of sugar cane, however, the pattern shown by old leaves is usually not present on young ones and it is, therefore, possible to observe the chlorotic areas in process of formation. It has been observed that they begin as small spots scattered about over the leaf. The spots grow and finally include much tissue that was at first a normal green color. In their growth, the spots that happen to be close together coalesce and form chlorotic areas of various sizes and shapes. While the areas resulting from the fusion of two or more spots are quite irregular in shape, the spots themselves show considerable regularity."

Further on in this paper he says:

"While a part of this enlargement was due to the growth of the leaf, most of it resulted from the spread of chlorosis in the normal green tissues bordering the spots."

Our studies indicate that the chlorotic areas in sugar cane are quite definitely determined before the formation of chlorophyll which enables the observer to detect them with the unaided eye. The areas which are to be chlorotic can certainly be detected in properly prepared microscope sections. These areas increase in size with the growth of the leaves, but so far as the writer has been able to determine they do not encroach on the surrounding green tissues and do not coalesce. The increase in size appears to be by cell division and growth and not by infection of surounding cells.

Kunkel also states that—

"It has been observed, however, that new spots sometimes arise in the normal green tissues as leaves unroll from the spindle."

My study of sections show that groups of cells so small that they cannot be seen with the unaided eye frequently occur in green areas of young leaves. It is very probable that groups of this kind enlarge with the growth of the leaf and give the appearance of new spots.

Kunkel also says—

"It has frequently been observed that the central areas of some spots are a normal green color and that only the borders are markedly chlorotic. Sometimes a small elongated chlorotic spot lies in the center of the green area."

The writer has observed the same character and has also been able to trace them by means of sections back into young leaves.

It will be readily seen from this discussion that the patterns cannot be detected on the young leaves previous to the formation of chlorophyll. Exposure to sunlight intensifies the patterns for a time but eventually the chlorotic areas undergo a slow formation of chlorophyll until it is practically impossible to detect the patterns in the very old leaves. This has been observed by Kunkel who says:

"In other varieties, the light, greenish areas, instead of deteriorating as the leaf ages, have a tendency to recover. They may become so green that it is difficult to distinguish them from areas of normal green color."

The presence of the great masses of trichomes makes it very difficult to study the early stages of the mosaic patterns on the tobacco. However, the writer is inclined to believe that they develope in the same manner as in the sugar cane; and it is certainly true that their later history is the same.

CYTOLOGICAL CHARACTER

The references to the chloroplasts in the early literature are brief and unimportant. Koning **(5)**, in his study of tobacco mosaic (1899) found that chloroplasts were disorganized. Ivanowski **(4)**, in his studies on tobacco mosaic (1903) reports that the chloroplasts in the chlorotic cells were yellowish and scarcely reacted to the starch test but later they contained as much starch as they could hold. Westerdyk **(9)** made a study of the tomato mosaic and reports (1910) that the chloroplasts of the chlorotic areas were slightly smaller. Melchers **(8)**, made a study of the mosaic of tomatoes and reported (1913), that no difference was detected in the number and size of the chloroplasts in the yellow and green areas. Matz **(7)**, made a study of the mosaic disease of the sugar cane and writes (1922) as follows:

"In the diseased tissues the chloroplasts are few and are evidently misshaped and broken up. In stained sections they look like mere ink spots, one or two in a cell. This destruction of chloroplasts is a symptom of sugar-cane mosaic and it fixes the seat of the disease more definitely. Apparently the cell walls and other cell contents are not affected, but the chloroplasts are gradually destroyed."

* * * * * * *

'It was seen that the breaking up of the chloroplasts begins with a reduction in their size. The chloroplasts in the healthy or green parts of the same leaf were normal in their size and numbers, while in the discolored or pale-green striped chloroplasts in all stages of reduction were noted.''

Dickson **(2)**, made a study of a considerable number of species of plants infected with mosaic and reported (1922) that the cells of the chlorotic areas contained less chlorophyll because of the fewer chloroplasts, less chlorophyll per plastid, the beaking down of the plastids or the general coalescence and degeneration of the plastids.

As a result of cytological studies on the mosaic of sugar cane, the writer of this paper wrote **(1)** as follows:

''A study of the cells of these leaves shows that the chloroplasts are more numerous in the dark-green than in the light areas. Therefore, it appears that in the case of the light-green areas the formation of the chloroplasts is inhibited but that with the exposure to sunlight this inhibition is gradually overcome.''

* * * * * * *

''The chloroplasts in the white or yellow areas were fewer in number and smaller than in the green areas.''

* * * * * * *

''The small chloroplasts of the mosaic cells are usually spoken of as having undergone a process of degeneration. The writer has studied the chloroplasts in the very young unrolled leaves and is satisfied that these chloroplasts are undeveloped rather than disintegrated. They have never reached normal development. Furthermore a study in a series of leaves from those just unrolling to the outermost on a plant shows that the chloroplasts of both normal and mosaic cells increase in size after being exposed to the light. These changes which are apparently due to age or light are so pronounced that there is very little difference in size of the chloroplasts in a leaf of the same age from a healthy plant. The writer is very doubtful if disintegration ever occurs in the case of primary infection (*i.e.*, infection from the seed).''

Since the writing of the above paper, Eckerson **(3)**, published the results of her studies on tomato mosaic in which she describes a flagellate organism found in the chloroplasts. In this paper she repeatedly refers to the ''dissolution'' and ''liquification'' of the chloroplasts.

In the light of these recent studies on mosaic it seemed advisable to extend my own studies; to repeat the studies on the sugar cane and to make a comparison with the tobacco. These two species were available in great abundance and since they are widely separated in the plant kingdom they appeared to be especially satisfactory for this purpose.

The plants for these studies were carefully selected. Healthy and diseased plants of sugar cane or tobacco of the same variety, age and approximately of the same size having been selected, the studies were

made on corresponding tissues under as nearly the same conditions as possible. The plants were grown within less than 100 yards of the laboratory which facilitated the immediate study of fresh tissues and the immediate killing and fixing of tissues for sectioning.

In the study of the sugar cane it must be remembered that there are two types of parenchyma cells in the leaves: (1) The single layer of cells which form a sheath around the fibro-vascular bundle and which we will refer to as the sheathing cells are very regular in size and shape. They are tubular, more or less cylindrical and placed lengthwise with the fibo-vascular bundle; and (2) the ordinary mesophyll cells which are very irregular in both size and form.

In the series of cross sections of leaves of healthy plants from the inside outward (Figs. 1 *a* to 1 *e*), beginning with leaves that are of an age corresponding to diseased plants in which the chlorotic areas can be detected without error, it will be readily seen that there is no very great variation in character of cells, nuclei or chloroplasts. Cross sections from corresponding parts of diseased plants (Figs. 2 *a* to 2 *e*) show that the nuclei are more or less enlarged or irregular in form and that there is a tendency for the chloroplasts to be slightly more numerous and larger in the outer leaves which are older and have had a longer exposure to light than in the inner leaves.

These characters are much more prominent in longitudinal sections than in cross sections as will be readily seen by a study of the figures 4–6 which were drawn from sections made from the same leaves as those from which figures 1 and 2 were drawn. The nuclei and chloroplasts in the sheathing cells in leaves from the inside of a healthy plant are practically the same (Figs. 3 *a*–3 *e*). An examination of sections from corresponding cells of a diseased plant (Figs. 4 *a*–4 *e*) show that the nuclei in the sheathing cells are slightly larger than in the corresponding cells of a healthy plant. Also the chloroplasts in the sheathing cells of the inner leaf are few and small but increase in size and number from the inner to the outer leaves. The same facts are brought out by a study of the nuclei and chloroplasts of the ordinary parenchyma cells. The nuclei and choroplasts are very uniform in cells of leaves of a healthy plant (Figs. 5 *a*–5*e*) regardless of age; but in corresponding cells of the diseased plants the nuclei are very generally larger and irregular in form, while the chloroplasts tend to increase in number and size from inner to outer leaves. A considerable number of plants were used in making these studies, but all the drawings 1 to 6 were made from two plants.

A more detailed study of the nuclei and chloroplasts of these same cells emphasizes the points previously referred to. The nuclei (Fig.

7) of the sheathing cells of a healthy plant are very regular and uniform in size while those from the sheathing cells of a diseased plant (Fig. 8, *a* to *e*) tend to be slightly larger and occasionally elongated. In the ordinary mesophyll cells of a healthy plant the nuclei (Fig. 9) are quite regular as compared with the nuclei (Fig. 10, *a* to *e*) from the corresponding cells of a diseased plant; many (but not all) of which are very irregular in size and shape.

The chloroplasts in the sheathing cells (Fig. 11) of a healthy plant are large and the markings well defined as compared with the chloroplasts (Fig. 12, *a* to *e*) from the corresponding cells of a diseased plant which are small and with poorly defined markings. The chloroplasts (Fig. 13) in the ordinary mesophyll cells of a healthy plant are large and regular as compared with the chloroplasts (Fig. 14, *a* to *e*) from the corresponding cells of a diseased plant. However, as previously stated, the chloroplasts in the chlorotic areas in the older leaves of a diseased plant are very nearly or quite normal in appearance. No disintegration of the chloroplasts were observed in any case except in the very old leaves which were decaying from old age or in tissues which were decaying as a result of the attacks of fungi.

The above studies were followed by the study of cross sections of leaves well within the spiral which had not been exposed to the direct light of the sun. These leaves were white and there was no indication of the formation of chlorophyll (Figs. 15–16). By carefully selecting severely diseased plants it was possible to find many groups of cells with enlarged or deformed nuclei. It appears that these groups of cells are destined to grow into the chlorotic areas. These cells no doubt increase in size and divide but the writer is very doubtful if the surrounding cells become chlorotic. It will be readily seen that it is difficult to secure evidence for or against this opinion but the study of spots on leaves that were showing the green failed to show any evidence that the spots were increasing in size except with the growth of the leaf. The writer is in disagreement with Kunkel on this point.

Groups of apparently normal cells so small that they cannot be detected by the unaided eye can be found within groups of diseased cells of the chlorotic areas. This no doubt accounts for the small island of green tissue surrounded by chlorotic tissue as observed by Kunkel and the writer. Likewise, groups of abnormal cells so small that they cannot be detected by the unaided eye are frequently found in sections made from apparently normal tissue.

Similar studies on healthy and diseased plants of tobacco do not show any great variation in the nuclei, but the history of the chloro-

plasts is exactly the same as in the sugar cane. The chloroplasts in the mesophyll cells of a healthy plant are large and regular (Fig 18–19) as compared with the chloroplasts from corresponding cells of the chlorotic areas of a diseased plants (Figs. 20 and 22.) In the study of a series of sections from young to old leaves of a diseased plant, there is a pronounced tendency for the cloroplasts to become normal in appearance with age and exposure to light and possibly other agencies.

The tendency of leaves of diseased plants of both sugar cane and tobacco to become more or less uniformly green with age and exposure to sun light is no doubt due to tendency of the chloroplasts in the cells of the chlorotic areas to increase in number and size. This could not possibly be the case if the chloroplasts were undergoing disintegration.

The intra-cellular bodies previously described by Kunkel are rare in sugar cane but are quite common in diseased tobacco (Figs. 23–25). They appear to be the same as the bodies described and figured by Iwanowsky in his studies on mosaic of tobacco. The writer is inclined to believe these bodies to be the result, rather than the cause of the disease although it is difficult to point out any very definite reasons for this opinion. Circles (Fig. 23) and some other points noted by Iwanowsky can be found occasionally in both diseased tobacco and diseased sugar cane but there does not appear to be any good reason for believing that they have anything to do with the disease. Small moving bodies are very abundant in the cells of mosaic tobacco plants but these same bodies can be found in healthy plants, although they are not so abundant. These same or similar bodies can also be found in diseased and in healthy sugar cane but are much less abundant than in tobacco. The writer failed to find any flagellate bodies attacking the chloroplasts as were described by Eckerson as attacking chloroplasts of the tomato. However, this phase of the question is worthy of further investigation.

SUMMARY

1. The mosaic pattern is indistinct on the very young leaves; becomes prominent with the growth of the leaves; then becomes less distinct with age.

2. The chlorotic areas tend to become green with age. This is probably due to the action of the sunlight on the chloroplasts.

3. The chloroplasts in the chlorotic areas are fewer in number and smaller than in the green areas. There is no evidence of disintegration.

4. The tendency of the chlorotic areas to become green with age is due to increase in number and size of the chloroplasts.

5. The chlorotic areas can be detected by cytological studies before the unfolding of the leaves.

6. The chlorotic areas increase in size by cell division and cell growth and not by the infection of surrounding cells or by a disintegration of the chloroplasts of the surrounding cells.

7. The formation of apparently new chlorotic areas in leaves is probably due to very small infected areas which increase in size with the general growth of the cells.

8. Green areas in a chlorotic area can be detected by cytological studies before they can be detected by the unaided eye.

9. The small size and number of chloroplasts is common to both sugar cane and tobacco when infected with mosaic.

10. The nuclei of diseased cane cells are usually enlarged or deformed, but this is not true of tobacco.

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EXPLANATION OF PLATES

Figs. 1*a* to **1*e***.—Cross sections from a series of normal leaves showing sheath cells of the fibro-vascular bundles and ordinary parenchyma cells. 1*a* is the youngest and 1*e* the oldest leaves in the series. Leaves *b* and *d* omitted.

Figs. 2*a* to 2*e*.—Cross sections from a series of mosaic leaves showing sheath cells of the fibro-vascular bundles and ordinary parenchyma cells. 2*a* is the youngest and 2*e* the oldest leaves in the series. Leaves *b* and *d* omitted. Note the reduced number and size of the chloroplasts and the abnormal nuclei as compared with Fig. 1*a* to 1*e*. Note also the chloroplasts tend to become normal in appearance with age.

Figs. 3*a* to 3*e*.—Longitudinal sections of sheath cells of the fibro-vascular bundles from the same leaves as Figs. 1*a* to 1*e*.

Figs. 4*a* to 4*e*.—Longitudinal sections of sheath cells of the fibro-vascular bundles from the same leaves as Figs. 2*a* to 2*e*.

Figs. 5*a* to 5*e*.—Ordinary parenchyma cells from same leaves as Figs. 1*a* to 1*e*.

Figs. 6*a* to 6*e*.—Ordinary parenchyma cells from same leaves as Figs. 2*a* to 2*e*.

Fig. 7.—Four nuclei from sheath cells of normal leaves. From same leaves as Figs. 1*a* to 1*e*.

Figs. 8*a* to 8*e*.—Four nuclei from sheath cells of mosaic leaves. From same leaves as Figs. 2*a* to 2*e*.

Fig. 9.—These nuclei from ordinary parenchyma cells or normal leaves. From same leaves as Figs. 1*a* to 1*e*.

Fig. 10.—Eight nuclei from ordinary parenchyma cells of mosaic leaves. From same leaves as Figs. 2*a* to 2*e*.

Fig. 11.—Chloroplasts from sheath cells of normal leaves. Same as Figs. 1 and 3.

Figs. 12*a* to 12*e*.—Chloroplasts from sheath cells of normal leaves. Same as Figs. 2 and 4.—(*a* inside leaf. *e* outside leaf.)

Fig. 13.—Chloroplasts from ordinary cells of normal leaves. Same as Figs. 1 and 5.

Figs. 14*a* to 14*e*.—Chloroplasts from ordinary cells of mosaic leaves. Same as Figs. 2 and 4. (*a* inside leaf. *e* outside leaf.)

Figs. 15–16.—Sections through leaves of mosaic plants which had not been exposed to the sun. No chlorophyll had been developed but many of the nuclei were abnormal.

Fig. 17.—Cross section of normal leaf of tobacco.

Figs. 18 and 19.—Cells from cross section of normal leaf of tobacco figured in 17.

Fig. 20.—Cross section of mosaic leaf of tobacco. Same age as 17. Note the abnormal chloroplasts.

Figs. 21 and 22.—Cells from cross section of mosaic leaf of tobacco, figured in 20. Note the abnormal chloroplasts and the intra-cellular bodies.

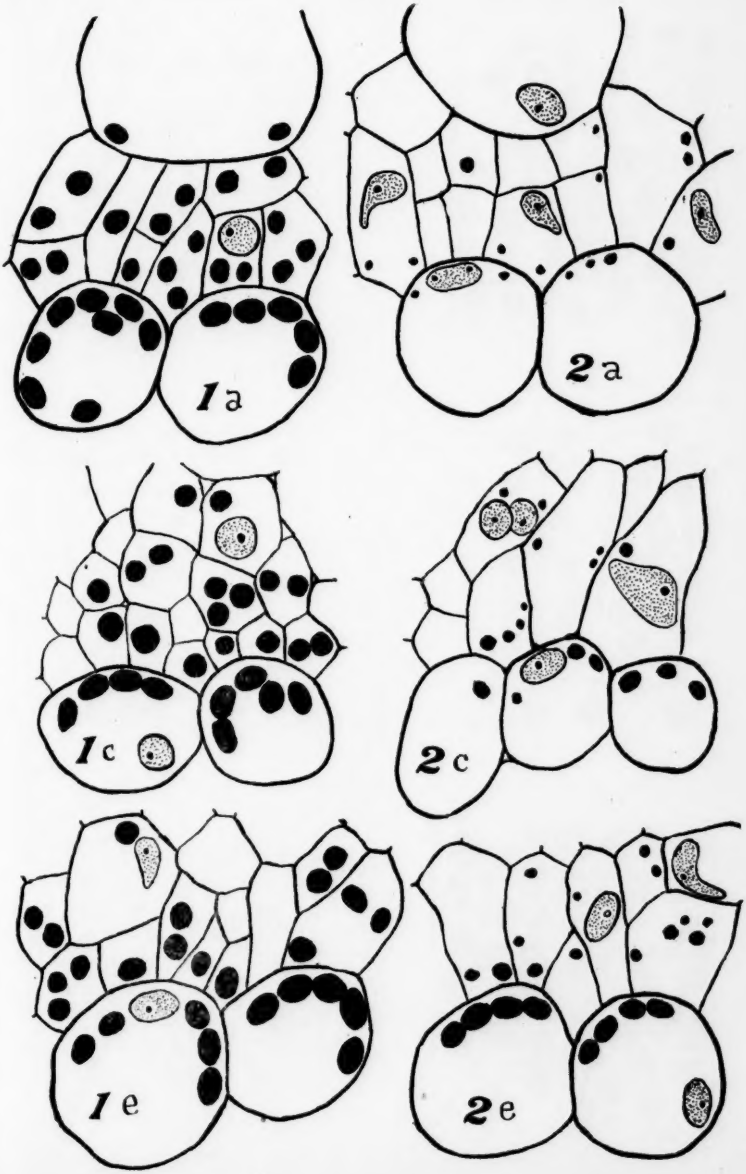
Fig. 23.—Cells from cross section of mosaic tobacco leaf, figured in 21. Note the intra-cellular body in one cell and the rings in the other.

Fig. 24.—Cell from cross section of mosaic of leaf of tobacco. Note the intra-cellular bodies and the abnormal chloroplasts.

Fig. 25.—Plant hair from mosaic tobacco. Note the intra-cellular body in the outer cell.

Fig. 26.—Nuclei and intra-cellular bodies from cross section of mosaic leaf of tobacco, figured in Fig. 20.

PLATE I



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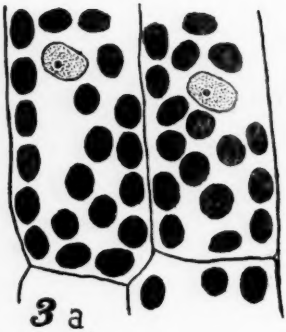

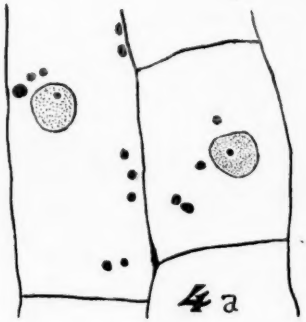

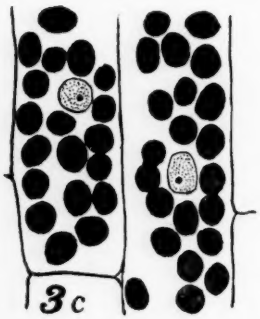

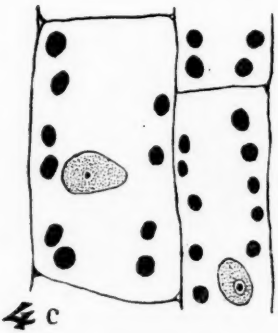

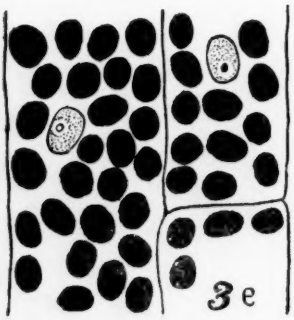

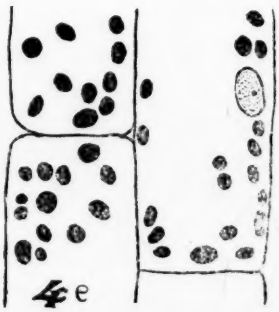

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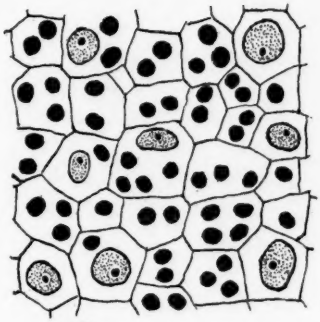

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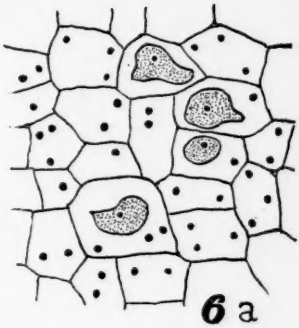

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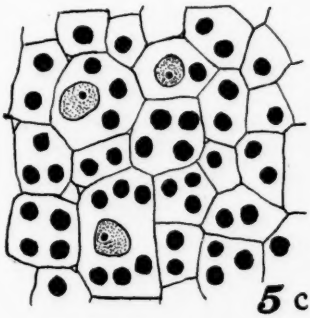

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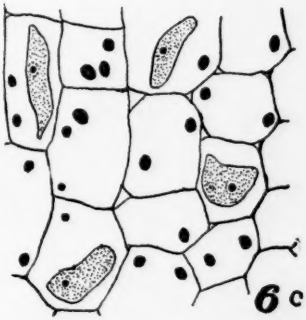

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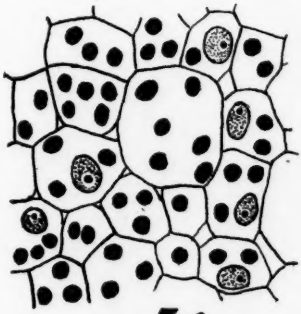

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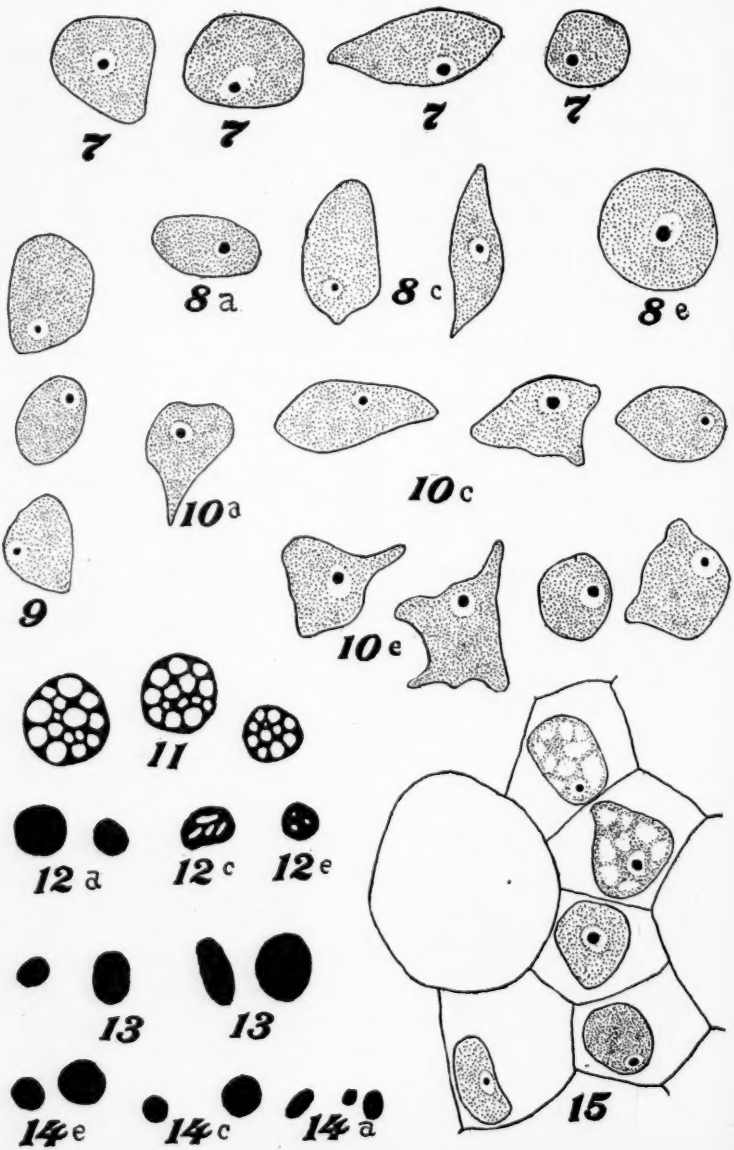
PLATE IV



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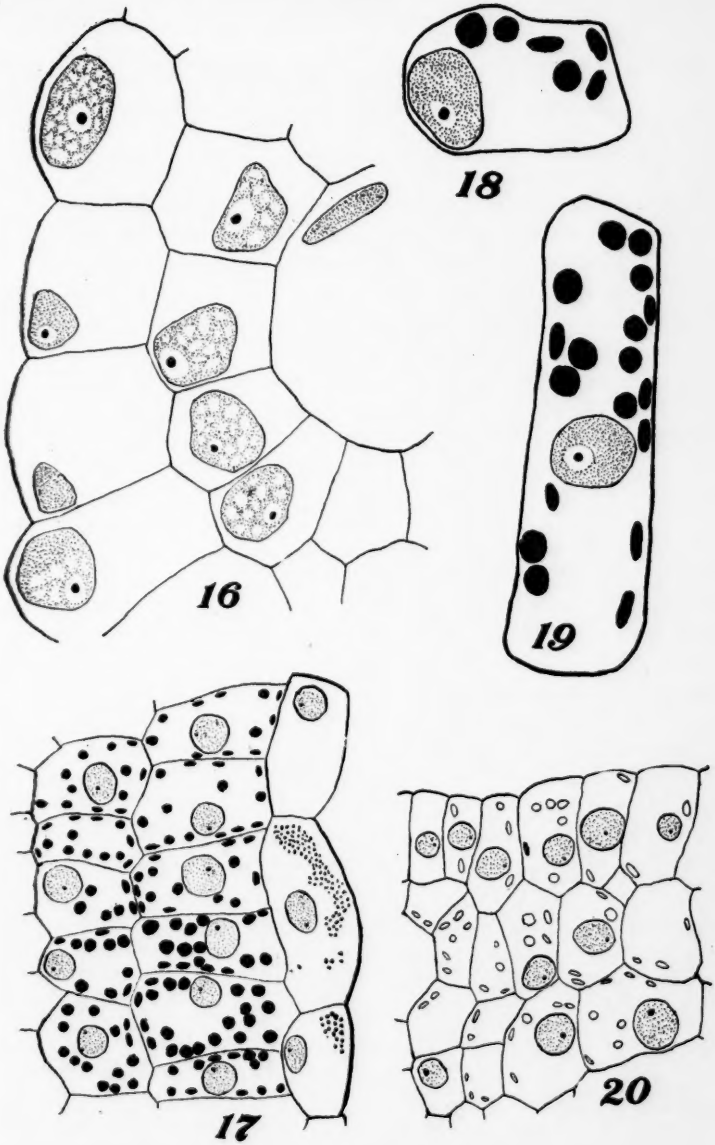

PLATE VI

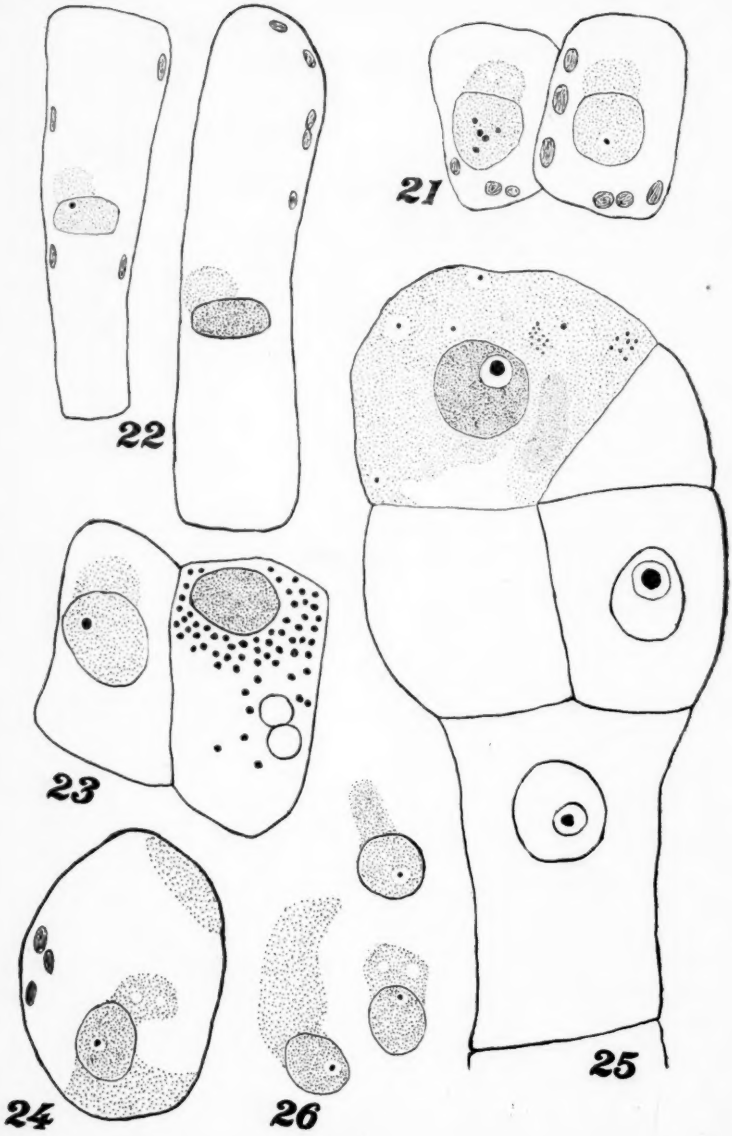

PHOTO-SYNTHESIS OF THE SUGAR CANE MOSAIC PLANT

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The symptoms of the mosaic diseases of many plants and the symptoms of plants with similar diseases such as "peach yellows" and "little peach" indicate a reduced or disturbed photo-synthesis, which usually results in a reduced growth or death or both.

References have been made in a number of papers on mosaic diseases to the amount of starch in the chlorotic cells of diseased plants but so far as the writer has been able to determine no special studies have been made on the relationship of the disease to photo-synthesis or any comparative studies on the photo-synthetic action of normal plants and those infected with mosaic. It is the purpose of this paper to give some of the accumulated data bearing on the photo-synthetic activities of some mosaic plants and the results of our own studies on the photo-synthesis of mosaic of sugar cane as compared with healthy plants.

The white, yellowish and light-green areas which are characteristic of mosaic plants indicates a reduction in amount or absence of chlorophyll, or an abnormal condition of same and most of the references in the literature indicate that this is true. Any of these conditions would necessarily interfere with the photo-synthetic activities of the plant. The limited references to this phase of the subject may be summarized as follows: In 1899 Koning **(8)** who was making a study of tobacco mosaic called attention in some cases to the disorganization of the chloroplasts. In 1900 Woods **(12)** reported that the light-colored areas of both tobacco and tomato plants infected with mosaic contained more than the normal amount of starch, which is contrary to the findings of most workers. And in 1902 **(13)** the same author makes this statement:

> "the disease is not primarily a disease of the chloroplasts; as Beijerinck thought, is evident from the fact that in the less pronounced cases the chloroplasts, though fewer in number, are not decreased in size or activity."

In 1903 Iwanowsky **(7)** reported that when the leaves of mosaic tobacco plants were young, the chloroplast in the light areas were yellowish and scarcely reacted to the starch tests, but that later the chloroplast contained a large amount of starch. This indicates that the plant passes through an abnormal condition from which it partly or completely recovers so far as the photo-synthetic processes are

concerned. In the same year Bouygues **(2)** reported the disappearance of the cell contents in the light areas of mosaic tobacco leaves. In 1910 Westerdyk **(11)** reported that in the case of tomatoes, the chloroplast in the cells in the yellow areas were smaller than those in the green areas and contained very little starch. In 1913 Melchers **(9)** reported on tomato mosaic as follows:

"No difference was detected in the number or size of the chloroplast in the yellow and green areas. That they were well supplied with starch was apparent."

The same author in the same year reported on potato mosaic as follows:

"The chloroplast throughout the yellow regions in the living material were a pale yellowish-green but contained considerable starch."

In 1918 Artschwager **(1)** reported an accumulation of starch in the leaves of leaf-roll potatoes. In this same year True and Hawkins **(10)** conducted chemical studies on spinach which indicated that both starch and sugar content were greater in diseased than healthy plants. Their results are summarized as follows:

"It appears that in spinach-blight the process of carbo-hydrate manufacture is not inhibited although it may be retarded."

These studies were chemical and not cytological and were made on diseased plants as compared with healthy plants; but not on chlorotic areas as compared with normal areas. It is doubtful if these results should be placed in the same category as the others which are referred to in this paper. In 1921 the author **(3)** of this paper reported the results of studies on "peach yellows" and "little peach". These studies indicated that the translocation of starch was partly or completely inhibited in the diseased trees. The accumulation of starch no doubt explains the thick, leathery texture of old leaves infected with either of these diseases. In 1922 Dickson **(6)** reported that in tobacco-mosaic leaves there was a reduction in the number of chloroplasts which in the case of the palisade cells were irregularly arranged in the lower half of the cells. In 1925 the author of this paper expressed the opinion as a result of the study of the histology and cytology of mosaic sugar cane **(4)** that the chloroplasts did not undergo disintegration but that their development was inhibited. In 1927 the writer of this paper reaffirmed **(5)** his opinion that the chloroplasts of the chlorotic areas did not undergo degeneration as a result of the disease but that they were undeveloped from the beginning and tended to become normal in appearance with age and exposure to sunlight.

A careful review of the data presented in the papers bearing on this subject, show some differences of opinion concerning the contents of the cells, especially with reference to the presence and character of the chloroplasts, but the paper on "peach yellows" and "little peach" by the writer **(3)** of this paper is the only one that the author has been able to find in which there is any effort to correlate the presence or absence of carbohydrates with the photo-synthetic activity of the plant.

During the past three years the writer of this paper has been making studies on the photo-synthetic activity of sugar-cane plants infected with mosaic as compared with normal plants. These studies were restricted to the microscopic examination of plants collected between 5 and 6 A. M. and between 2 and 3 P. M. The tissues were treated in various ways to bring out the desired information. The plants for study were grown within 100 feet of the laboratory. In some cases the studies were made immediately on free-hand sections while in other cases the sections were prepared by longer processes.

These studies showed that the normal plants and the green areas of the diseased plants performed their proto-synthesis in the normal manner and showed a large amount of starch in the afternoon and very little in the morning, while the white and light green or yellowish areas showed a small amount of starch in the afternoon and practically none in the early morning (Figs. 1 to 4). It was very evident that the starch-forming power of the mosaic cane was reduced in proportion to the amount of infection while the power of translocation was practically unimpaired. This is the reverse to the findings of the writer in the case of the "peach yellows" and "little peach" in which the cells of the diseased leaves are filled with starch but in which the translocation is greatly reduced or completely inhibited. These studies indicate that we may have two types of disease; the one generally represented by the various mosaics in which the photo-synthetic activities are greatly reduced. The second which is represented by "peach yellow" and "little peach" in which starch is formed in the leaves but not transported to other parts of the plant, the result being that the leaves become hard and leathery. The accumulation of starch in the leaves of "leaf roll" potatoes which has been referred to by Artschwager and the leather texture of the leaves of such plants, may indicate that the "leaf roll" of potatoes should be classed with the "peach yellows" and "little peach". These studies also showed that the old leaves of sugar cane infected with mosaic produced more starch than the young leaves of the same plants. This is no doubt due to the

fact that the chloroplasts in chlorotic areas of mosaic plants tend to increase in size and number with the age of the leaf as indicated in another paper by the author **(5)**.

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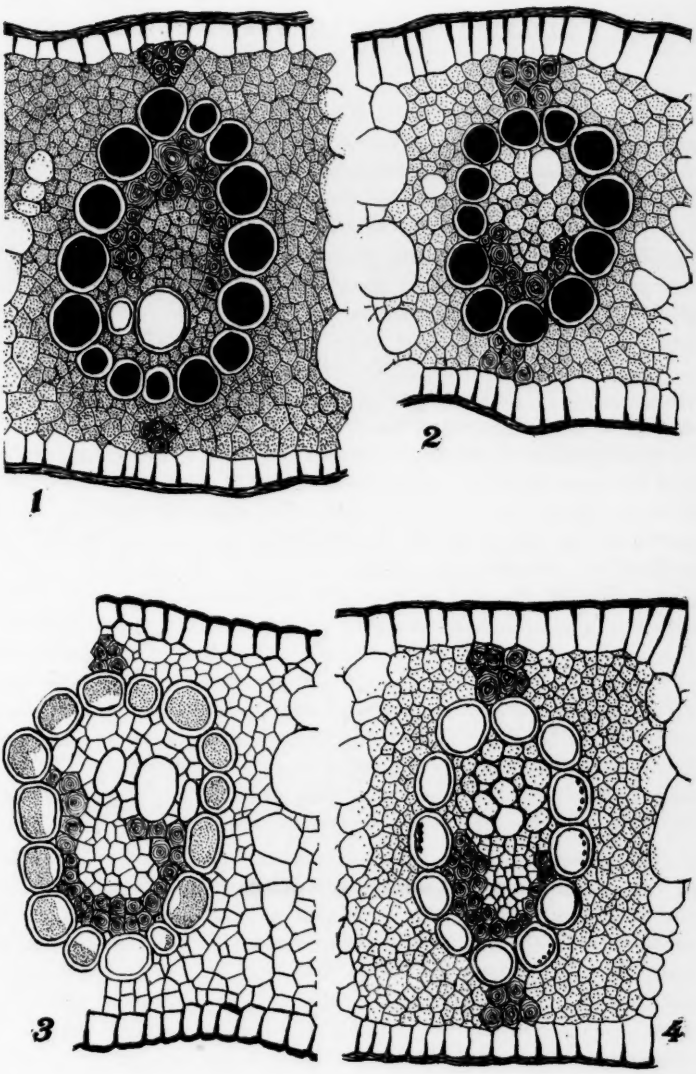
EXPLANATION OF PLATES

Fig. 1.—Cross section of leaf of normal plant at 3:00 P. M.
Fig. 2.—Cross section of leaf of mosaic plant at 3:00 P. M.
Fig. 3.—Cross section of leaf of normal plant at 6:00 A. M.
Fig. 4.—Cross section of leaf of mosaic plant at 6:00 A. M.

PLATE I



THE UNROLLING OF THE LEAVES OF SUGAR CANE

MELVILLE T. COOK, Chief of the Division of Plant Pathology

The unrolling of the leaves of monocotyledonous plants, such as sugar cane and corn is such a common phenomenon that it appears to have been overlooked by students and writers. While pursuing studies on the mosaic disease of the sugar cane the attention of the writer was attracted to the anatomical structures involved in the unrolling of the leaf. Before discussing this point it will be necessary to call attention to the structure of the mature leaf. In the mature leaf we find three sizes of fibro-vascular bundles. The largest constitute the parallel veins which are so well defined in the leaf as to be visible to the naked eye and extend from epidermis to epidermis. The other two sizes are arranged alternately and the number between any two of the veins is variable, but fairly constant for each variety. The medium-sized bundles are always in contact with the outer or lower epidermis and may or may not be in contact with the upper or inner epidermis. The space between the upper and lower epidermis which is not taken up by the fibro-vascular is filled with parenchyma cells of many sizes, the smaller ones being next to the bundles and to the lower epidermis which are in contact with the larger bundles coming in contact with the upper epidermis. The medium-sized cells are between the bundles. The largest cells are in contact with or very near the upper epidermis. In some cases they supplant the ordinary type of epidermis and in fact are large epidermis cells which extend far into the tissues of the leaf and have a thin cuticle on the exposed surface. Therefore, there is much more parenchyma near the upper than near the lower epidermis and the large cells are nearer the upper epidermis.

It is these large parenchyma or giant cells that are most important in the unrolling of the leaves. When the leaf is young the fibro vascular bundles are poorly developed and there is a much greater uniformity in the size of the parenchyma cells than in the mature leaf. The fibro-vascular bundles mature with the increase in age and certain of the parenchyma cells near the inner or upper epidermis increase in size very rapidly and become the giant cells. The lateral enlargement of these giant cells force the leaves to unroll and assume the normal position.

These large cells are probably filled with water and with the

unrolling of the leaf they are exposed to the direct rays of the sun which naturally aids evaporation. The loss of water from these cells naturally results in a contraction and upward rolling of the cells which is so characteristic of plants of this kind during periods of drouth.

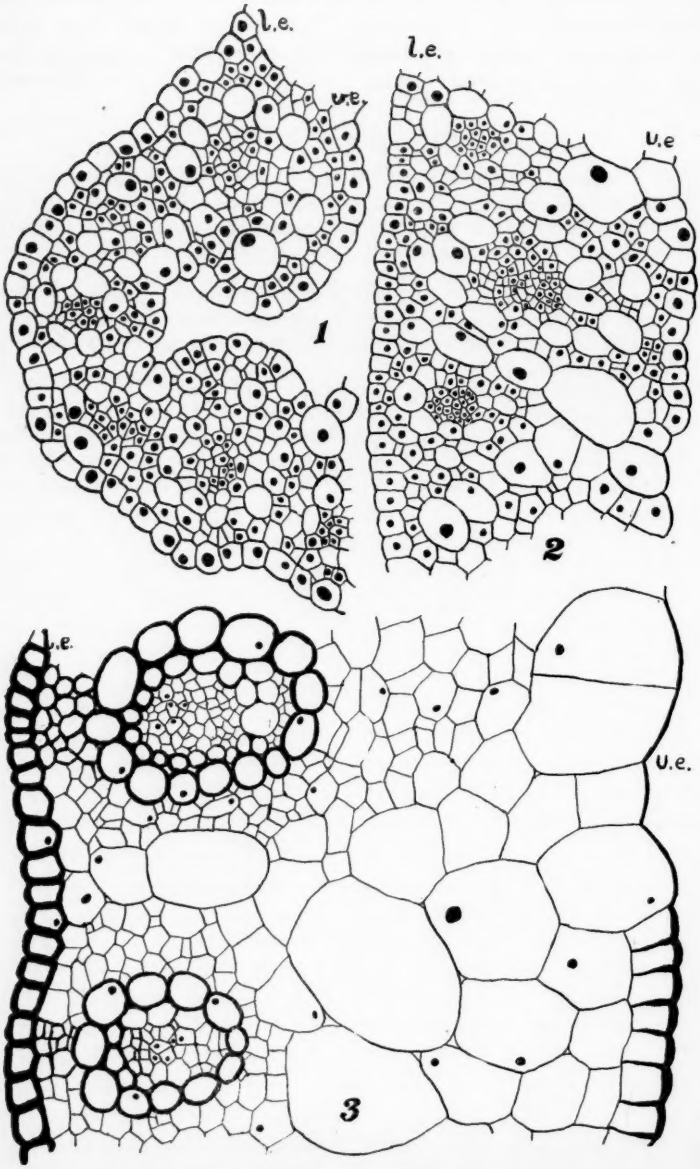
EXPLANATION OF PLATES

Fig. 1.—Cross section through a very young leaf before it has started to unroll. *u. e.*=upper epidermis. *l. e.*=lower epidermis. Note the very young fibro-vascular bundles; the uniform character of the mesophyll cells, some few of which are enlarging.

Fig. 2.—Cross section of an older leaf just starting to unroll. Note the increased development of the fibro-vascular bundles and the great variation in size of parenchyma cells as compared with Fig. 1.

Fig. 3.—Cross section of a leaf fully unrolled. Note the fibro-vascular bundles which are almost fully developed and the great variation in size of the parenchyma cells. Note the very large parenchyma cells near the upper epidermis. It is the lateral enlargement of these cells which forces the unrolling of the leaf.

PLATE I



ONION-LEAF ANTHRACNOSE

J. A. B. NOLLA, Assistant Plant Pathologist

The fungus flora of Porto Rico has been the subject of detailed study during the last decade. A number of investigators have worked assiduously on various problems involved and have made very important additions to our knowledge of the subject. The present paper comprises the study of a new anthracnose disease of onions which was discovered by the writer in one of the eastern districts of the Island in January 1924.

The destructive nature of the disease makes its study of interest not only to Porto Rico where onion-growing promises to become an important industry but to other onion-growing countries in the world, in which this crop so far as reports go, is not subject to this malady. There is here presented a brief report on the investigation of this disease and a description of the pathogene. A popular account was published by the writer in 1925 **(4)**. A note on this disease was also given by Cook **(1)**.

SUSCEPTS

Allium cepa L. (Market onion) has been most seriously affected and the false shallot to a lesser extent. Infection has been produced on the latter, both under laboratory and field conditions. Plants of all ages are equally susceptible, although most of the damage appears to occur in plants three months old and during rainy weather. However, that plants of this age happen to be so seriuosly attacked under the prevailing weather conditions, is no indication that they are at this age most highly susceptible. The outbreaks of this disease here recorded appear to be correlated with the amount of rainfall and the length of the rainy periods.

Varietal Susceptibility.

The work of Walker **(5, 6, 7)** on the resistance to onion smudge, which is also an anthracnose disease, led the writer to undertake a comparative study of the resistance of white, yellow and red varieties to the pathogene in a field of about .60 acre. Seedlings 40 days old were transplanted to plots 4×40 feet. Four plots were planted to red onion (Red Wetherfield and Red Bermuda), four to White onion (White Bermuda) and the rest of the field to yellow onion (Yellow Globe and Yellow Bermuda). The disease made its appearance at

about the same time on all varieties. Careful observations showed that red, yellow and white varieties are equally susceptible. The tropical varieties (Bermuda onion) showed no less susceptibility to the pathogene than the temperate-zone varieties tested.

DISEASE

We have named this disease the *"Onion Leaf Anthracnose"* to avoid confusion with smudge which is often referred to as "onion anthracnose" and with diseases known as "onion leaf-spot".

History and Range.

As stated before in this paper the disease was first found by the writer in January 1924, in the eastern part of Porto Rico. In 1925 it was found in one of the northern districts and in the same farm where it had been discovered in 1924. In 1926 and 1927 material with anthracnose infection was obtained from the northwestern and northern sections. It does not appear to have been reported outside of Porto Rico.

Importance.

Data were gathered on the number of plants which were entirely killed by the disease, those which did not attain full maturity and those which were only slightly affected. Comparison of the yield from an uninfected field with conditions otherwise similar to those of diseased plots were made. From our observations it appeared that from 45 to 55 per cent of the crop was lost.

The damage to the bulbs while usually indirect is generally severe. The disease prevents the complete formation of the bulbs when the attack is early. In this way bulbs from diseased plants will be undersized. When attacks are late the disease opens the way for bacterial or other rots.

SYMPTOMATOLOGY

Morphologic Symptoms.

The disease is primarily of the leaf blade but the bulb scales may also be affected. The characteristic morphologic symptoms on white and yellow varieties are elliptic or oval tiny whitish spots which grow in all directions. During rainy weather the pathogene causes a rotting of the tissues. This destruction extends along the surface of the leaves and down to the bulb scales. Inner-bulb scales are not affected.

The symptoms on the red onions, especially the Red Wetherfield, are similar to those of the yellow and white varieties except that

in the early stages of spot formation a red stain becomes prominent on all the injured tissues. This color soon takes on a violet appearance. This violet stain occurs before any fruiting bodies arise and disappears with age.

The diseased tissues in all varieties become paper-like and brittle when dry. Old spots may be almost colorless, but more commonly they are yellowish. They are sub-elliptic to irregular in shape.

Signs.

Conidia are produced abundantly in acervuli in the spots. The spore masses are creamy, flesh-like or pink to ferruginous. Ascospores may be found under certain conditions.

Histologic Symptoms.

The effects on the diseased tissues are those characteristic of necrotic diseases. As has been already stated the first indications of the disease are minute spots. These lesions enlarge. Hydrosis is the first histologic symptom which accompanies the penetration of the pathogene, which establishes both intra- and inter-cellular relationship. This is followed by the disorganization of the protoplasts and discoloration of the cell walls. This brings about a collapse of the cells, the first to succumb to the effects of the pathogene being those of the pallisade layer. The fungus penetrates farther down into the outer parenchyma cells, desintegrating them and then into the vascular bundles where it runs through and between the cells. Toward the later stages all that is left of the tissues is a skeleton of epidermis and broken cell walls.

ETIOLOGY

Name, History and Classification of the Pathogene.

The pathogene under consideration was first thought to belong in the genus Gloeosporium. Later setae were found, which places it in the genus Colletotrichum. Since the fungus appears to be new to science it is given the name *Colletotrichum Chardonianum* in honor of Carlos E. Chardón, the present Commissioner of Agriculture and Labor of Porto Rico.

COLLETOTRICHUM CHARDONIANUM spec. nov.

Mycelium is hyaline, white gray or dark and even greenish, depending on the medium in which it is growing. It is 1.41–6.63 u thick, septate and profusely branched. (Pl. I, Figs. 10 and 11.)

Acervuli applanate, scattered, or gregarious (Pl. I, Figs. 30–31). These arise under the epidermis and break through it. They vary

in color from ferruginous to brown, sometimes flesh-colored. The setae are brown, septate, slender, acute. in a few cases blunt at the tips, 98–170 × 4.8 u (Pl. I, Fig. 1). Conidia are oblong, in the majority of cases have both ends rounded. In some cases only one end is rounded while the other tapers to a blunt end. In other cases they are slightly curved, 6–80 × 1.7–7.0 u (Pl. I, Fig. 14). The conidiophores are simple, cylindric, terete or with rounded base and pointed tip, 7.9–79.5 × 1.72–3.7 u (Pl. 1, Figs. 12 and 13). A few perithecia were once found in culture, but were not produced later. The writer does not feel justified in making a description of the perfect stage from the insufficient material on hand and his failure to obtain it repeatedly.

CULTURAL CHARACTERISTICS

Pure cultures of the fungus were obtained in the usual manner and a study was made of its behavior in different artificial media. From pedigree cultures, poured plates of saccharose (3 per cent) agar, glucose (3 per cent) agar, lactose (3 per cent) agar, potato-dextrose agar, corn-meal agar and oatmeal agar, were inoculated. Measurements of colony growth in centimeters were made. Conidia were also measured.

On Potato-dextrose agar.

Neutral gray discoloration of the substratum; aerial mycelium in dense tufts, gray, growth profuse; acervuli salmon or ochraceous salmon.

On Oatmeal Agar.

Medium unchanged in color, mycelium hyaline or whitish, greenish masses here and there, acervuli numerous, ochraceous salmon or flesh-ocher, in distinct zones, but later filling up all the inter-zonal region.

Corn-meal Agar.

Substratum underlying acervuli brown to black; aerial mycelium scanty or none,[1] when present consisting only of short threads, hyaline; acervuli numerous, flesh-ocher to apricot buff, in zones or scattered.

Glucose Agar.

Substratum underneath acervuli mummy brown; aerial mycelium dull white and in some places smoky or dark, acervuli large, flesh-

[1] The pedigree cultures used were under one month of age when fruiting is heavy. Older cultures show less fruiting.

ocher or apricot buff to cinnamon-rufous, in zones; setae present, numerous.

Saccharose Agar.

Substratum Dresden brown underneath the acervuli, ochraceous-buff elsewhere; aerial mycelium profuse, dark, over old growth, white; acervuli numerous, large, rufous to ferruginous, zones not well-marked, setae few.

Lactose Agar.

Substratum flesh-colored with mummy brown discoloration under old acervuli; aerial mycelium in short, whitish threads, scanty; acervuli numerous, large, flesh-colored to ferruginous, zoned at first.

Dextrine Agar.

Substratum unaffected in color, aerial mycelium scanty, short, white threads; acervuli numerous, large, rufous to ferruginous, not zoned.

TABLE I

SEVEN-DAY-OLD GROWTH OF *C. Chardonianum* n. sp. IN DIFFERENT ARTIFICIAL MEDIA

(Diameter of growth in centimeters)

Culture	Potato dextrose agar	Oatmeal agar	Cornmeal agar	Glucose agar	Saccharose agar	Lactose agar	Dextrine agar
1	8.0	7.8	7.0	8.0	8.1	7.7	7.4
2	8.0	7.8	7.0	8.0	8.0	7.6	7.5
3	8.3	7.8	7.8	7.8	8.0	7.7	7.5
4	8.3	7.8	7.8	7.7	8.0	7.8	7.5

Pathogenicity.

Inoculation experiments were made as follows:

(*a*) A small portion of a healthy plot of onions (24 square feet) was sprayed with a suspension of conidia obtained from fresh lesions. This was done at 4 P.M. on a day in January. The plants were not protected from the sun and they received no watering. However, the air was warm and moist. It was conducted during a rainy period. Symptoms as already described (small whitish spots) appeared in from 3 to 5 days. Out of 34 plants so sprayed 31 showed symptoms at the end of 5 days.

(*b*) Strong, vigorous plants in clay pots were similarly treated. In this experiment the plants were covered with bell jars lined with moist filter paper. Symptoms appeared in from 3 to 5 days.

These two series of experiments prove beyond any possible doubt the power of *C. Chardonianum* to produce infection of onion plants.

Life History.

The life history of this pathogene probably involves only the asexual or conidial stage, although the sexual stage may also occur in the field.

The primary cycles occur as lesions on leaves of full-grown transplants in the field.

PATHOGENESIS

Inoculation.

Infected debris from the previous season is probably the chief source of the inoculum. It seems possible that the mycelium of the fungus is carried over to succeeding seasons in these old plant fragments. When the rainy season approaches, coincident with maximum development of the onion plant, it appears that a conidial crop is produced from this hibernating mycelium. Spattering rain brings about the transfer of the inoculum (conidia or perhaps ascospores) from this debris to onion leaves. Here the primary cycles are started, which by subsequent production of pink or creamy conidial masses furnish a constant source of inoculum for the secondary cycles.

INCUBATION

Germination of conidia was studied in Van Tieghem cells in the usual manner, at a temperature of 21° C. The first evidence of protrusion of germ tubes appeared at the end of three and one-half hours and germination was at its maximum at the end of four and one-half hours.

The spores of this species like those of most species of Gloeosporium, Colletotrichum and Glomerella, become septate prior to germination. Germ tubes grow from the ends of the spores (Fig. 18, 20, 23), although not infrequently from the sides (Fig 16). Germ tubes are of various lengths and in almost every case an appresorium is borne at the tip (Figs 17–22) of each tube. The plasmic contents of the spore creep into the appresorium and a septum is laid, thus cutting it from the germ tubes (Figs. 17–23). Primary appresoria germinate by sending out penetration tubes which enter the suscept and develop into a myclium or by production of secondary or tertiary appresoria. It is evident that appresoria may be subsequently produced again and again from primary or initial appresoria depending on environmental conditions. The spore upon falling on the infection court probably makes a first attempt to germinate, sending out a germ tube whose elongation may be arrested by want of moisture. An appresorium is formed at the end of the short

tube. This is able to withstand unfavorable conditions. When better conditions of humidity are restored the appresorium in turn attempts to germinate in the same manner as the conidium. In this way several appresoria may result from one conidium before entrance or penetration is effected.

The germ tubes enter through the stomata of the leaves or through wounds, but penetration may occur through the cuticle probably by mechanical pressure as reported by Dey (2) for *Colletotrichum lindemuthianum*. The germ tube upon effecting entrance or penetration undergoes a change into a thicker hypha or primary mycelium, Leach (3). Further development of the pathogene brings it into a closer relationship with the suscept parts manifested in a series of changes which constitute infection.

Infection.

The primary mycelium makes its way into the epidermal cells, which it soon destroys. It runs between the cell wall and the plasma membrane. After reaching this stage the mycelium sends out any number of hyphae which grow in every direction, penetrating and killing the cells. These hyphae branch again and again and soon the tissues are traversed by the infecting hyphae. The necrotic spmptoms which accompany the infection of the tissues are the result of the reaction of the suscept cells to the substances produced by the invading hyphae. Toxic substances are probably produced soon after invasion since the latent period of infection appears to be short (2–4 days) and furthermore, the succession of changes from hydrosis to complete cell disorganization, seems to come with considerable rapidity. Under favorable conditions of atmospheric humidity, acervuli soon arise over the surface of the lesions. They are formed in breaks of the epidermis and may grow together in masses. Conidia make up the greater bulk of these masses which are pinkish or creamy. These spores constitute the inoculum for the cycles.

SAPROGENESIS

All observations tend to show that the mycelium in the necrotic areas of the leaves, lives over in a saprophytic manner until the coming season. Conidia are produced during the saprogenesis stages and furnish the inoculum for primary cycles. Whether one or more crops of conidia are produced by the mycelium in this stage is not known.

Secondary cycles constitute the most important phase in the

disease. They are initiated continuously by conidia produced in the primary cycle and are in all respects similar to the primary cycles.

EPIPHYTOLOGY

That stage in the life of the suscept, just before or during bulb formation, seems to furnish the most favorable conditions for the attack of the pathogene.

Temperature.

Spore suspensions of the fungus were incubated at different temperatures. It was demonstrated that spores fail to germinate at 15° C and below. The following are the results of germination in tap water at different temperatures: At 18° C., 39.15 per cent; at 21° C., 41.92 per cent, at 25° C., 92 per cent; at 27° C., 86 per cent; at 30° C., 80 per cent; at 33° C., 64 per cent. Parallel trials conducted with distilled water showed that germination is equally good in distilled water as in tap water. It is seen that germination is at its maximum at 25° C. but is poor at lower temperatures of 21° C. and 18° and at a higher temperature of 33° C. In the field the range in which the disease seems to appear more commonly is 23° C.–30° C. In cultures the optimum temperature seems to be 27° C. See table II. In general, in the three media growth was best at 27° C. with maximum production of conidial masses.

TABLE II

SEVEN-DAY-OLD GROWTH OF *Colletotrichum Chardonianum* IN CENTIMETERS IN DIAMETER

Temperature	Potato dextrose agar	Corn-meal agar	Oat-meal agar
6° C.	0	0	0
9° C.	0.1	2.3	1.0
12° C.	2.2	4.5	3.6
15° C.	2.7	3.8	5.2
18° C.	5.5	6.0	6.3
21° C.	7.5	7.5	7.6
25° C.	8.5	7.8	7.8
27° C.	9.0	7.8	7.8
30° C.	8.0	7.0	7.0
33° C.	7.8	7.0	6.5

We do not feel justified in assuming temperature to be the most important factor in epiphytotics although coupled with moisture it may have great influence in limiting their extent and destructiveness.

Moisture probably plays the most important role in determining

the nature and severity of outbreaks of this disease. It seems essential in effecting the dissemination of conidia. The occurrence of the disease in the field and the production of secondary cycles is dependent to a large extent on precipitation.

CONTROL

It is quite doubtful whether we can resort to any eradicatory measure in the control of this disease. The removal of diseased leaves and plants to prevent further spread of the pathogene sounds logical, but general practice tells us it is highly improbable that the average farmer will gain anything by that method. The production of conidia under field conditions in such great numbers curtails the possibilities of the application of this eradicatory practice, since secondary cycles will occur with the same ease.

Protection.

Spraying and dusting with suitable liquids or dusts will eventually come into use more and more. Three factors should be considered in the general application of these protective methods, namely, the cost of application as compared to the gains from it, the adhesive power of the dusts or liquids and the general effectiveness of these fungicides.

Preliminary laboratory trials have been conducted with various dusts to find the effect on the spores of the pathogene. Those tried were: Kolo-dust, dusting sulphur, copper lime dust, Banks' Colloidal copper, corona colloidal copper, copper hydroxide and Killtone copper dust.

The following results were obtained in triplicate trials with spore counts of 4,000 and using the dusted-slide method employed at Cornell University.

Corona colloidal copper	no germination
Banks' colloidal copper	36.47% germination
$Cu(OH)_2$	37.40% germination
Killtone copper dust	9.00% germination
Copper lime dust	62.84% germination
Kolodust	57.47% germination
Dusting Sulphur	60.50% germination
Check	59.50% germination

General observations of the germination processes.

In Banks' Colloidal copper brown appresoria were abundant, produced successively from the same germ tube; germ tubes are very long and normal in growth, soon giving rise to a cobwebby

mycelium. In copper hydroxide no appresoria were observed and germ tubes were very short; this was also the case with Killtone copper dust. Kolodust: appresoria abundant and germ tubes long Dusting Sulphur: appresoria present; germ tubes extremely long, much more so than in Kolodust. Copper lime dust: appresoria present; secondary conidia also produced in large numbers; germ tubes very long and profusely branched. The failure of sulphur dusts to inhibit spore germination is in line with our general knowledge of the non toxic properties of the sulphur fungicides to anthracnose fungi.

The data and observations given above on the germination of conidia of *C. Chardonianum* in various fungicides suggest a rather effective action of Corona colloidal copper, Killtone copper dust, Banks' Colloidal copper and copper hydroxide. Apparently the first two are more promising than any of the others. However, it must not be overlooked that the adhesiveness of these dusts to the waxy surface of the onion leaf has to be tested before any more definite steps to their application in the field are attempted. So far the writer has been unable to test the adhesiveness and relative efficiency of these fungicides under field conditions.

SUMMARY

(1) An anthracnose disease of the leaves and bulb scales of the onion is described.

(2) Market onion (*Allium cepa L.*) and a multiplier variety of *Allium cepa* L. often referred to as false shallot are affected.

(3) There does not exist any resistance in the yellow, red or white varieties to the disease.

(4) Tropical varieties of onion are as susceptible as the temperate-zone types.

(5) Plants of all ages are equally susceptible.

(6) The symptoms on the leaves may be described as elliptic or oval spots. On red varieties a red stain appears on young lesions.

(7) The pathogene is described as a new species, *Colletotrichum Chardonianum*.

(8) Growth of the causal fungus in carbohydrate media was excellent. It was especially good in starch-containing media.

(9) Infection experiments under control conditions demonstrate the ability of *C. Chardonianum* to produce disease. Infection occurs primarily through the stomata but the germ tubes may penetrate through the cuticle.

(10) Conidia germinate in water at a temperature of 21° C. in 3½ to 4½ hours. During germination of conidia, primary, secondary and even tertiary appresoria are produced. Also secondary conidia. Temperatures of 18° C. and 33° C. seem to inhibit germination, while conidia germinate readily at 25° C. In synthetic culture media the fungus grows best at a temperature of 27° C. In the field the disease appears during seasons when temperature is 23° C–30° C.

(11) The pathogene apparently lives over from one season to the other as mycelium in debris on the soil.

(12) The conidia seem to resist the action of the sulphur fungicides. An effective action of copper fungicides, particularly colloidal copper, has been observed in laboratory experiments.

This investigation was begun in the Insular Experiment Station but the bulk of the work was done in the Laboratory of Plant Pathology, Cornell University, Ithaca, N. Y.

I owe an acknowledgment to Dr. Mel. T. Cook, Chief Pathologist, for helpful advise during the early studies on this disease, to W. R. Fisher of the Department of Plant Pathology at Cornell University, who kindly made some of the photographs, and finally to Prof. H. H. Whetzel of the Department of Plant Pathology, Cornell University, for valuable suggestions and criticisms and for reading the manuscript.

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PLATE I

Fig. 1 = Setae of *Colletotrichum Chardonianum* n. sp.
Fig. 2 = Two fertile hyphae conjugating.

Fig. 3 = Fertile hypha with terminal conidium.
Figs. 4 and 7 = Fertile hyphae.
Figs. 5, 6, 8 and 15 = Types of fertile hyphae with terminal conidia.
Fig. 9 = A fertile hypha with cells giving rise to one-celled conidiophores which bear conidia at the tips.
Figs. 10 and 11 = The mycelium of *C. Chardonianum.*
Figs. 12 and 13 = Conidiophores of *C. Chardonianum* bearing conidia at the tips.
Fig. 14 = Conidia of *C. Chardonianum.*
Fig. 16 = Germinated conidia conjugating.
Figs. 17 and 22 = Conidia germinating in water, giving rise to primary, secondary and even tertiary appresoria.
Figs. 18 and 20 = Two conidia germinating by a short tube and an appresorium.
Fig. 19 = A conidium germinating and producing primary and secondary appresoria.
Fig. 21 = A germinating conidium with primary appresoria.
Fig. 23 = Conidia germinating into a long tube bearing at the tips secondary spores.

PLATE II

Fig. 24 = A longitudinal section through a healthy onion leaf (outlined with aid of camera-lucida).
Fig. 25 = A section through a lesion of a diseased leaf. Note the hyphae penetrating through and running between cells. The destruction of the palisade cells is evident.
Fig. 26 = Another section through a diseased leaf showing destruction of palisade cells and also hypha penetrating through cells of vascular bundles.
Fig. 27 = View of surface of onion leaf showing a few spores germinating and penetrating through the stomata. Note the production of appresoria. (Outlined with aid of a camera-lucida.)
Fig. 28=Section through epidermis showing an appresorium germinating and the tube penetrating through a stoma. The very early stages of a pathological condition: branches of the primary mycelium penetrating the suscept cells.
Fig. 29 = Meyclial threads (hyphae) as seen within and between cells in the vascular bundles (highly magnified). (Outlined with aid of camera-lucida.)

PLATE III

Fig. 30 = Shows lesions on the leaves of onion. The leaf on the left shows the early stages of the disease; that on the right the more advanced stages with masses of acervuli.
Fig. 31 = Enlarged base of the onion plant of Fig. 32 showing the acervuli of the fungus arising on the surface of the leaf bases. Notice poor root system from imperfect nutrition.
Fig. 32 = Typical case of onion plant affected with *C. Chardonianum.* Notice the diseased leaves and the bases of leaves already destroyed.
Fig. 33 = Culture of *C. Chardonianum* on hard potato dextrose agar.

PLATE I

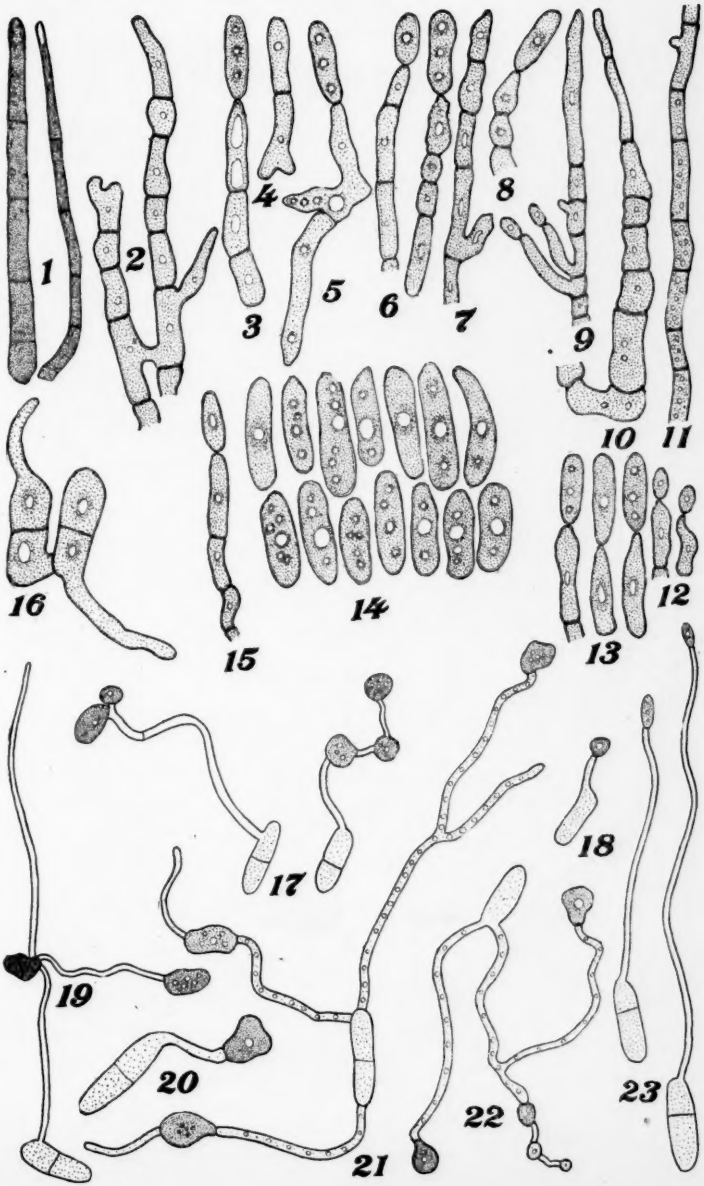


PLATE II

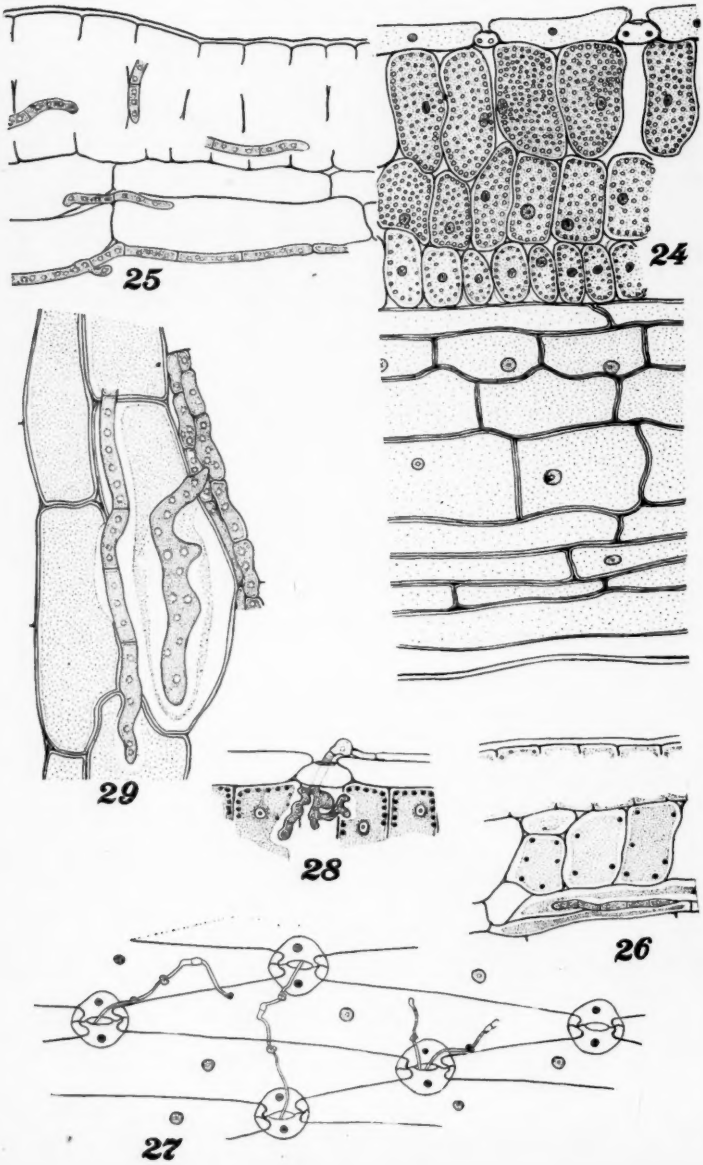
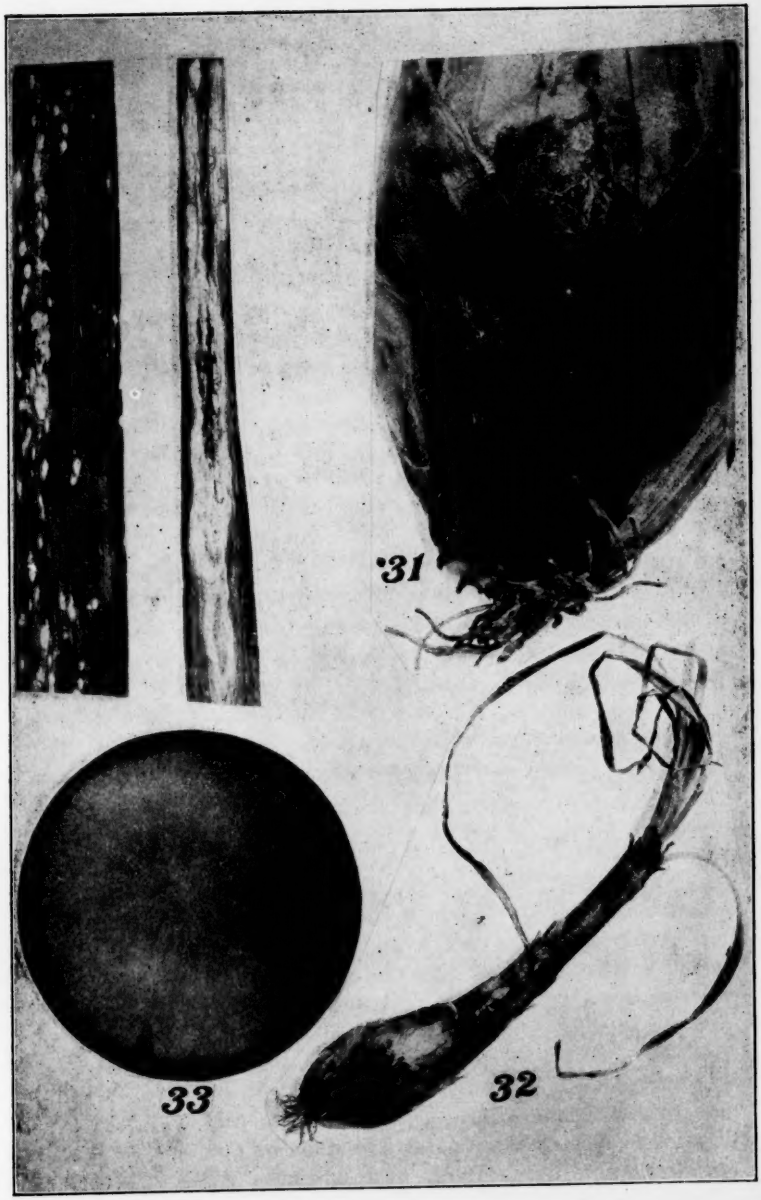


PLATE III



MANGO WITHER-TIP

(*Colletotrichum gloeosporioides* Penz.)

J. A. B. Nolla, Assistant Plant Pathologist

The fungus *Colletotrichum gloeosporioides* has been reported from time to time as causing troubles of various kinds on a number of suscepts. However, its true pathogenicity or active parasitism has been the subject of much speculation and a matter of conjecture. On citrus fruits, for instance, *C. gloeosporioides* has been held not to be an active pathogene, Smith **(3)** and Fulton **(1)**. Winston **(5)**, using a large number of strains of *C. gloeosporioides,* found no active pathogenicity exhibited on young fruits of various citrus species. Nowell in his book on diseases of tropical plants, page 211, states it is mainly a saprophyte. The author **(2)** came forth with the statement that this fungus is an active pathogene in Porto Rico. He found it to be the cause of a heavy drop of the young fruits of the orange, pomelo and Chinese dwarf lemon.

In the present short paper the writer intends to bring more evidence of pathogenicity of strains of *C. gloeosporioides.* He almost predicted the ability of *C. gloeosporioides* to produce wither-tip on the mango **(2)**, when he stated that "mango twigs when tender seem to be susceptible to the attack of *Colletotrichum gloeosporioides*" (see his plate I, fig. 3). This statement was based on results which he obtained with spore-spray inoculations of avocado, mango and pomelo strains of *C. gloeosporioides* on the unopened buds of the mango.

Early in November 1926 the writer directed his attention to a few mango trees in the station grounds. It was during a short dry spell and there were no signs of a fungus infection. Two weeks later, with the coming of heavy rains and a new flush in the trees, there occurred a very rapid withering of the young tender twigs and buds. There was also considerable spotting of the leaves, manifested as tiny, brownish spots between the main veins, which later increased in size. This resulted in long, sometimes narrow, necrotic areas on the tender, pinkish leaves which caused a breaking and splitting at the infected areas. Soon, the infection which apparently starts in and around the unopened leaf buds, extends down the shoot as far as the upper limit of the preceding growth. The tender foliage soon dies and falls to the ground. Acervuli of the

fungus appear readily on the surface of the withered twig, especially on the scars left by the leaf petioles.

Isolations were made from various places of infection. Spore-spray inoculations with pure cultures of the pathogene were made, covering the buds in the best manner to insure control conditions. The same symptoms as observed with natural infection were reproduced with artificial inoculations. The pathogene, *C. gloeosporioides*, same strain as used in inoculation was recovered from the infected twigs.

This is a case where a fungus held to be a saprophyte under many circumstances, exhibits in some of its strains a strictly parasitic action on one of its suscepts. We might here recall a similar situation existing with *Macrosporium parasiticum* Thüm, the cause of the black mold of the onion, whose pathogenicity has not been fully accepted. Teodoro (4) has pronounced it as an aggressive parasite. Others have held rather dubious views as to its secondary nature.

It seems probable that fungi which have heretofore been known as saprophytes or weak parasites on necrotic areas of living plants, or the intermediate living tissues, will gradually, through adaptation, bring about changes in their ontogeny which will eventually place them in the category of the more highly specialized forms—the active parasites.

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FIG. 1.—Mango tree with a severe infection of *C. glocosporioides* on the twigs

SOME NEW AND INTERESTING PORTO RICAN LEAFHOPPERS

By H. L. Dozier[1]

Opportunity is here taken to publish a few interesting records and additions to the leafhoppers of Porto Rico. The writer wishes to

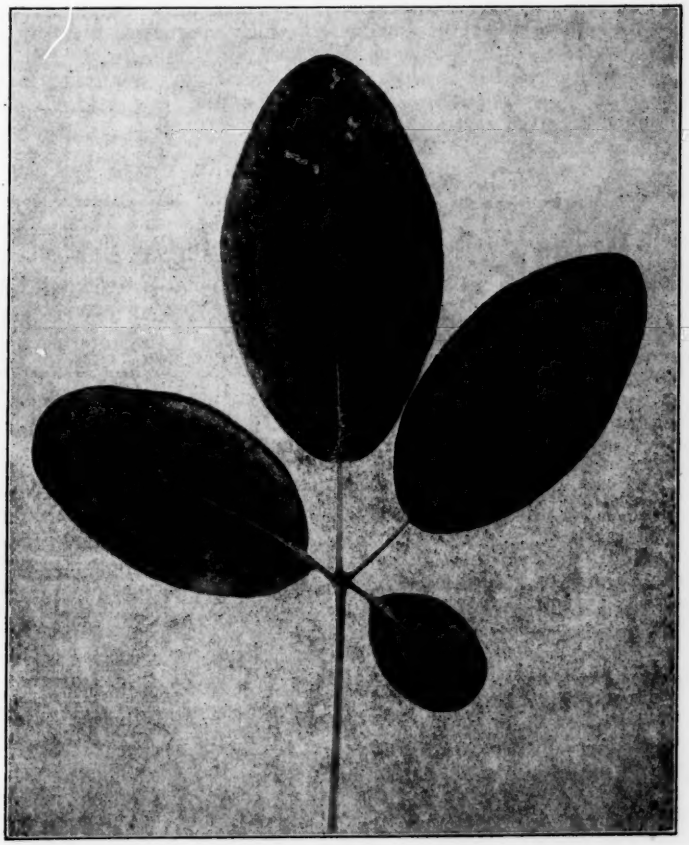

FIG. 1.—Leaves of Roble, *Tabebuia pallida*, showing the work of *Protalebra tabebuia* Dozier

thank Mr. W. L. McAtee of the U. S. Biological Survey for determining specifically the Eupterygid species included in this paper.

[1] Formerly Chief Entomologist of the Insular Experiment Station.

Protalebra tabebuiae, new species

Head rather broadly rounded although slightly produced. Venation of wings typical of the genus.

General color of body pale yellowish-white, the vertex and thorax in most specimens with a broad median longitudinal band of orange on dorsum; ground color of the elytra a golden yellow with the inner claval margin, an oblique band across the middle, and another band beginning at the hind margin of the clavus and running across the cross veins, distinctly fuscous; in some specimens there is a Chinese-white irregular patch on the outer costal margin just above the middle fuscous band; the crossveins infuscated, the apical area denoted by them is hyaline. Legs whitish.

Length to tip of elytra, 2.75 mm.

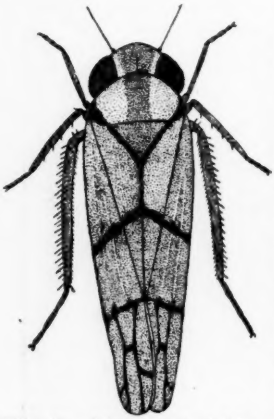

FIG. 2.—Adult of *Protalebra tabebuiae* Dozier (Original)

Described from numerous specimens of both sexes taken on underside of leaves of "Roble", the West Indian Box Tree, at Río Piedras, Porto Rico, March 10, 1925. It was found abundant in all stages October 22, 1924, and has been observed to be rather abundant throughout the entire year. "Roble", *Tabebuia pallida,* is widely used as a shade tree in Porto Rico and its wood is of much economic importance. While this leafhopper often becomes very abundant on it, causing considerable "speckling" of the foliage, the Roble is so hardy that it is able to support large numbers without any apparent injury.

Protalebra similis Baker
(1899 Psyche, 8, p. 403)

A dozen adults were swept by the writer from sweet-potato foliage at Vega Baja, Porto Rico, October 15, 1924. It does not appear to be at all abundant.

Protalebra brasiliensis Baker
(1899 Psyche, 8, p. 405)

This species is the most abundant and generally distributed *Protalebra* in Porto Rico being commonly met with in cane fields and in weedy places. It is the same species discussed and figured by Wolcott (Jr. of the Dept. of Agri. of Porto Rico, V, p. 31) under the name *Erythroneura comes* Say.

Protalebra bifasciata Gillette
(1898, Proc. U. S. Nat'l. Mus., 20, p. 711)

A single specimen taken by beating a thorny leguminous bush in ravine near Juana Díaz, Porto Rico, February 11, 1925. Recorded from Brazil and Jamaica.

Empoasca minuenda Ball
(1922, Proc. Ent. Soc. of Wash., Vol. —)

The writer found this very small species abundant on undersides of avocado leaves at Río Piedras, Porto Rico, October 22, 1924, and it also attacked the young avocado nursery stock at the Insular Station in large numbers.

Dikraneura (Hyloidea) depressa McAtee
(1926, Jr. New York Ent. Soc., Vol. XXXIV, p. 162)

This species has been recently described from two females and a male collected by G. N. Wolcott at Vega Alta, Porto Rico, January 21, 1920, and the new subgenus Hyloidea erected for it based on the extraordinary depressed or flattened shape. The original description is given here to make it more available to workers in Porto Rico:

"Female: Head and thorax yellowish in ground color with a percurrent russet to dusky marking covering all but narrow anterior margin of vertex, disk of pronotum, and all but extreme lateral angles of scutellum; apical third of scutellum jet black. Tegmen lemon-yellow, a dusky blotch on middle of clavus, a dusky band over inner crossveins, and a jet black spot on first crossvein; tegminal apex sometimes touched with dusky. Underside stramineous throughout except for the black apex of ovipositor; bristles on ovipositor sheath white. Eighth sternite convex medianly, slightly concave laterally. Male similar to female, marking of head and thorax more or less tinged with reddish laterally; tegmen anterior to fourth crossvein also with a pinkish cast. Venation as in Fig. 15. Length, 2.25–2.75 mm.

"Holotype male, allotype, and another female, Vega Alta, Porto Rico, January 21, 1920, G. N. Wolcott (U. S. N. M.)."

These remarkable leafhoppers are to be found on the undersides of the leaves of *maga, Thespesia grandiflora,* in limited numbers. The writer found them abundant at Bayamón, Nov. 17, 1924, and made the following color notes. The last instar nymphs are of a general pale whitish color, the elytral pads pale with an orange-red longitudinal stripe; the sides of the pronotum and the head except the eyes orange; the eyes pale bluish; scutellum with reddish-brown markings; the second and third abdominal segments a deep reddish-brown. Length 1.75 mm. These nymphs remind one of

Uncle Sam's red, white and blue. Both the adults and nymphs lie closely appressed to the leaf surface, mostly along the mid-ribs, moving when disturbed with a "sideling" or sidewise movement, rarely jumping.

Joruma pisca McAtee
(1924, Fla. Ent., Vol. 8, No. 3–4, p. 34)

The writer took a single specimen at Aguirre, Porto Rico, March 1, 1925, that has been identified by McAtee as this species.

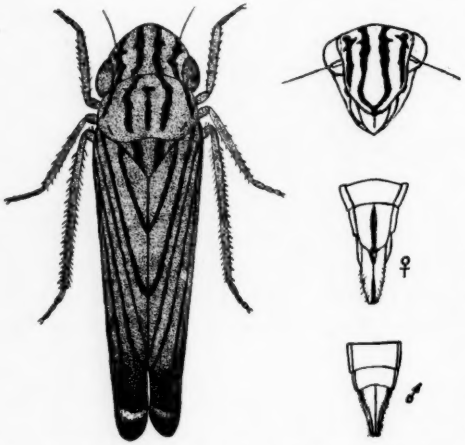

FIG. 3.—Adult female *Cicadella coffeaphila* Dozier, frons and genitalia (Original)

The two following species have been long confused with each other on acount of their very similar general appearance and habitat and have long been placed under the name *Tettigonia occatoria* Say (Wolcott, Insectae Portoricensis, p. 259). Upon examination of the large series in the collections of the Insular Experiment Station and the American Museum of Natural History, the writer found that they not only are not Say's *occatoria* but represent two distinct undescribed species. *Cicadella occatoria* is a somewhat smaller, less robust species, and has a single black dot on the pale frons just below the apex of the vertex margin (see Ball, Proc. Iowa Acd. Sci. VIII, p. 23, 1901). The writer has not found *occatoria* either in his personal collecting in Porto Rico or in the various collections represented. Specimens, however, are at hand from the American Museum of Natural History collections, taken in June 1911 at Laudet and Long Ditton, Dominica, B.W.I., that must be placed as typical *occatoria*.

Cicadella coffeaphila and *C. coffeacola* are both abundant throughout the mountanous coffee-growing regions, particularly the former species, occurring on the coffee and many other host plants among which may be mentioned the jobo and *Inga laurina*. Both species

so far are known only from the Island of Porto Rico and appear to be endemic.

Cicadella coffeaphila, new species

Distinguished at once from *Cicadella occatoria* by its larger size and different marking on frons.

Vertex as long as basal width, strongly produced beyond the eyes, obtusely sounded, nearly two-thirds as long as the pronotum. Pronotum convex, about as broad at posterior margin as the head. Elytra long and narrow.

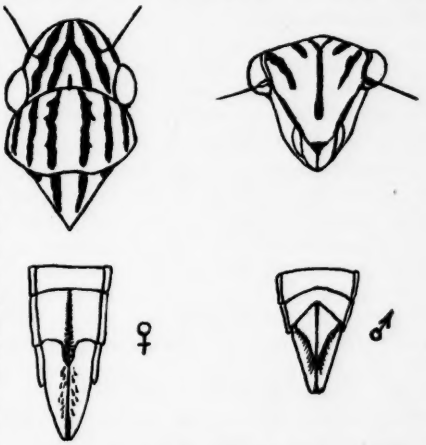

FIG. 4.—*Cicadella coffeacola* Dozier, **showing head, frons, and female and male genital segments (Original)**

General color greenish, the vertex, anterior third of pronotum, and scutellum partially, yellow. Vertex with four irregular more or less longitudinal stripes or vittae that extend over onto the frons where the two median ones converge just before the apex. Pronotum with five more or less broken and irregular black vittae. Scutellum with two rather thick black vittae. The elytra dark green with the veins heavily marked with black, just before the apex is a crescent-shaped transverse band of yellow. Body beneath yellowish, the abdomen along middle marked longitudinally more or less with black. Male genital plates distinctly yellow contrasting with the dark pygofers. Legs pale.

Genitalia: female segment over twice as long as the preceding, the median line elevated into a strong keel, the posterior margin strongly angled, the apex formed by the convex keel. Male ultimate segment well-rounded on posterior margin; plates broadened at base, rapidly narrowed to very long acute points that are not or scarcely exceeded by the pygofers.

Length to tip of elytra, 6–6.25 mm.

Described from numerous males and females in the collection of the American Museum of Natural History collected for the most part by Lutz and Mutchler from the following localities in Porto Rico: Cayey, May 30, 1915; Aibonito, June 1–3, 1915; Barros, June 4, 1915; Mayagüez, July 24, 1914, Frank E. Watson; Ja-

yuya, June 1, 1915, H. E. Crampton; Adjuntas, June 26, 1915; and a female collected at Yauco, August 24, 1922, by Sein and Wolcott (Acc. 234–22); and a female collected by the writer on El Yunque, February 17, 1925.

Cicadella coffeacola, new species

Very similar in general appearance with *Cicadella coffeaphila* but easily distinguished by the different markings on vertex, frons and pronotum.

Vertex greatly produced beyond the eyes, obtusely rounded, length and width subequal, two-thirds as long as the pronotum. Pronotum about as broad at posterior margin as the head, convex. Elytra long and narrow.

General color greenish, the vertex yellow with four black stripes or vittae, the two median ones converging to a point at the apex, the outer lateral margins outlined with black. Frons yellow with black median stripe and the lateral ones of the vertex continued over on frons part of its length, the lower sides of frons with black edging; clypeus black. Pronotum greenish, yellow along the anterior third, six distinct black longitudinal stripes running semi-parallel. Scutellum yellow, with two black median stripes and a black spotting in the upper angles. Elytra deep green, the veins broadly marked in black. Body beneath for the most part yellow, the abdomen marked with broken black along median length. Male plates yellow, the pygofers black. Legs pale.

Genitalia: female segment twice as long as preceding, male ultimate rather deeply incised on hind margin; plates rather broad at base, rapidly narrowing to long acute points, greatly exceeded by the pygofers.

Length to top of elytra, 6–6.25 mm.

Described from a female taken at Río Piedras, Porto Rico, Aug. 1921, G. N. Wolcott (Acc. 266–21); a female collected by the writer on coffee, El Yunque, Feb. 17, 1925; and numerous males and females collected by Lutz and Mutchler in American Museum of Natural History collection from Cayey, May 30, 1915; Aibonito, June 1, 1915; and Adjuntas, June 26, 1915.

Macropsis rugicollis, new species

Easily distiguished by the striking contrast of the bright red head and thorax with the black body and elytra.

Form rather long. Anterior margin of the pronotum moderately and roundingly angulate, produced on the middle distinctly beyond the anterior margin of the eyes, the posterior margin only slightly

emarginate. Elytra long with the tips broadly rounded, nervures raised.

Color: Entire head a bright red with exception of the very dark reddish-brown eyes. Pronotum bright red with a rather narrow band of black outlining its anterior margin but extending laterally only to about half the width of the eyes above. Remainder of the body, legs and elytra a dark blue-black.

Length, 5.50 mm.

Described from two males taken on the top of mountain at Cerro del Cacique, Santo Domingo, December 17, 1924, by F. Sein at about 5,000 feet elevation, probably from a shrub or tree as members of this genus are so far as known tree-inhabiting forms.

NOTES ON PORTO RICAN SCALE PARASITES

By H. L. Dozier[1]

The following notes are here given as a small contribution to our knowledge of the enemies of certain scale insects in Porto Rico. The writer wishes to express his thanks to Mr. A. B. Gahan of the United States National Museum for his kindness in helping to compare and identify the parasites recorded in this paper.

Leptomastix dactylopii Howard

(1885, U. S. Bur. of Ent., Bul. 5, p. 23)

This species was described briefly by Dr. Howard in 1885, and again in 1892 (Proc. Ent. Soc. Wash., II, p. 237) he states that is a not uncommon parasite of the common mealy-bug in the greenhouse at Washington, D. C., and notes the following:

"Miss Lillie Sullivan has found it the present season infesting mealy-bugs upon house plants, and informs me that she can at once recognize infested scales by the fact that they lose almost entirely their wax or meal-like covering and swell up into yellow objects closely resembling dipterous puparia. She has shown me several from which the parasites have emerged and I have been greatly struck by this resemblance which is heightened by the fact that the parasite in issuing cuts off a cap at the end of the scale insect, just as the dipterous insect forces off the end of its puparium. This is an abnormal habit so far as I know, as allied parasites are accustomed to gnaw holes through their hosts, removing the epidermis in small particles and leaving no cap. The resemblance of the swollen mealy-bug to a dipterous puparium is so strong that only by close search with a strong lens can the observer, by finding the minute legs and antennae, be certain of its identity."

These early observations of Dr. Howard have been confirmed by the writer.

Upon further study and comparison of material, *dactylopii* may prove to be identical with the European *histrio* described by Mayr in 1875, and this is highly probable as both species seem to be rather variable in color and size.

Female: Head somewhat lenticular, slightly convex; ocelli arranged in triangle, the hind ones farther apart from each other than from the inner margin of the eye; antennae very long, as long or slightly longer than the body, slender and clothed with delicate short hairs; the scape as long as the first two funicle joints together, pedicel twice as long as wide, and about half as long as the following joint, club as long as the last two funicle joints com-

[1] Formerly Chief Entomologist of the Insular Experiment Station.

bined, slightly broader than the funicle and rounded on end. Thorax moderately arched, mesonotum somewhat shining, with scattered setae. Scutellum dull, with sparse setae; at its posterior apex are two distinctly larger, more prominent black setae. Vertex and thorax with indistinct scale reticulations under high microscopic power. Abdominal segments difficult to distinguish.

The general color of the female is honey-yellow with distinct reddish tinge on the mesonotum, the antennae and eyes blackish, the hind margin of the pronotum, scutellum, dorsum of abdomen, and hind femora more or less dusky.

FIG. 1.—*Pseudococcus citri* parasitized by *Leptomastix dactylopii*

Male: Similar to female in structure but distinguished at once by its antennae which are distinctly longer than the entire body and the funicle is furnished with numerous long hairs which are not arranged in whorls. Much darker than the female, the amount of black on thorax quite variable, the mesonotum, distinctly yellow. Antennae, hind tibiae and tarsi fuscous.

Length of female, 1.50 mm.; male, 0.97 mm.

As the original description is now inaccessible to most workers, the above brief re-description is given. It is drawn up from a female reared by the writer from *Pseudococcus citri* at Río Piedras, Porto Rico, June 8, 1925, and a series of three females and four males reared by F. Sein at same locality from the same host, November

1925. There is also at hand a male reared by the writer at New Orleans, La., September 1922.

Achrysopophagus seini, new species

Resembling a *Cheiloneurus* very closely and placed in *Achrysopophagus* only because of its slightly narrower head and the absence of distinct scrobal grooves. Very close to *A. dactytopii* Howard but differs in having the fore-wings less enfumed and the stigmal vein is very different.

Female: Head slightly wider than long; ocelli arranged in an acutely angled triangle. Antennal scape slightly expanded beneath,

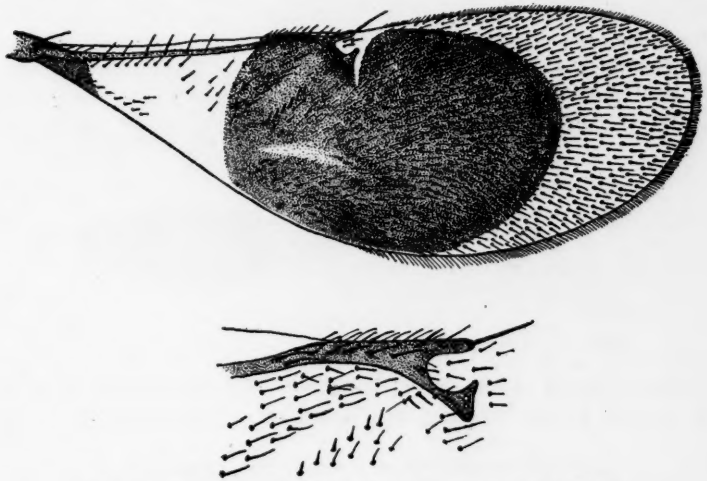

FIG. 2.—Forewing of female *Achrysopophagus seini* Dozier

nearly four times as long as its widest width; pedicel as long as the first two funicle joints combined; first four funicle joints sub-equal, the fifth and sixth longer and wider; club three-jointed distinctly wider than the scape and of about the same length, obliquely truncate. Mesothoracic scutum over twice as wide as long. Scutellum about as long as wide, with the characteristic tuft of black bristles, distinctly reticulated. Mesoscutum with dark hairs anteriorly and on hind margin but with numerous setigerous punctures in the silvered area. Abdomen shorter than the thorax, the ovipositor sheath distinctly exserted.

General color a yellowish orange, the abdomen usually slightly darker; eyes dark. Antenna testaceous yellow except a fine streak along center of upper margin of scape, the pedicel, first funicle joint

partly, and the club, which are brownish-black. Legs pale yellowish white, the hind femora and tibiae with slight infuscations. Forewings with characteristic enfumation on disc as in Fig. 2.

Length, exclusive of ovipositor, 1.10–1.4 mm.

Male: Antennae entirely different from those of female, easily differentiating the sexes, uniform light brown in color; funicle joints furnished with partial whorls of long diverging hairs. General color dark-brown, the front and middle legs pale, the wings hyaline without embrowning.

Length, .78 mm.

Described from a female reared by the writer (U. S. National Museum type No. 40351) from *Pseudococcus citri* material on croton at Río Piedras, Porto Rico, June 21, 1925, and a series of four females and one male reared by Francisco Sein in November 1925 from the same host and locality. The mealy bugs were parasitized by *Leptomastix dactylopii* and the parasitized individuals were placed in shell vials by Mr. Sein, and from some of these issued this species. *Arfchrysopophagus scini* is most probably secondary on the *Lepto-*

FIG. 3.—Antenna of female *Achrysopophagus scini* Dozier

mastix, although absolute proof is lacking. All material was mounted in Canada balsam on slides and is not entirely satisfactory.

Achrysopophagus gahani, new species

This species is very closely allied to *A. scini* and *dactylopii* How. and was first placed as the latter. The original description of *A. dactylopii* is too meager to allow for positive identification but through the kindness of Mr. A. B. Gahan of the U. S. National Museum the Porto Rican specimen was carefully compared by him with the type of *dactylopii* and found to be a distinct and apparently undescribed species, *dactylopii* having the ovipositor very distinctly exserted, the head decidedly longer than broad when viewed from the front, and the antennal club is much larger than in *gahani.*

Female: Antennal scape much expanded beneath, pedicel as long as first two funicle joints combined, the fifth and sixth joints distinctly wider and longer than the preceding funicle joints; club three-jointed, distinctly larger and wider than remainder of antenna.

Scutellum with the characteristic tuft of black bristles at apex, reticulated. Abdomen about as long as thorax, the ovipositor sheath only slightly exserted. The structure of the stigmal vein is very distinctive, readily separating it from *seini*.

General color yellowish orange. Forewings hyaline and bare on basal third except slight embrowning at base, remainder distinctly embrowned with only the apical tip hyaline as in Fig. 4. The antennal scape testaceous yellowish, lower edge infuscated along basal half,

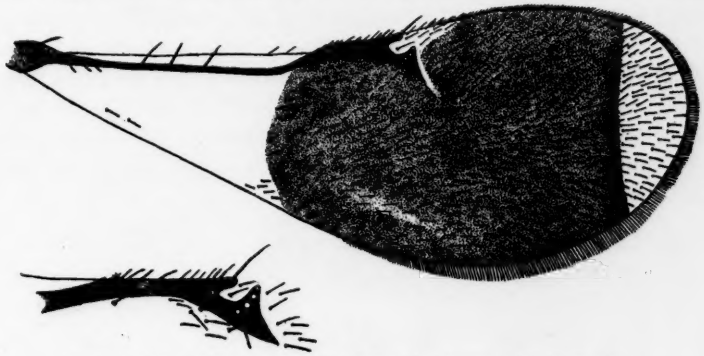

FIG. 4.—Forewing of female *Achrysopophagus gahani* Dozier

the pedicel and funicle distinctly darker yellowish-brown, the club deep fuscous.

Length, exclusive of ovipositor, 1.25 mm.

Described from a single female reared by the writer from *Pseudococcus citri* material on croton June 18, 1925, at Río Piedras, Porto Rico (U. S. National Museum type No. 40352). It is most probably a secondary parasite. Dr. Howard in describing his *A. dactylopii* states that a large number were bred from the common mealy-bug in company with *Leptomastix dactylopii* Howard.

FIG. 5.—Antenna of female *Achrysopophagus gahani* Dozier

Thysanus nigrus (Ashmead)

(1900 Proc. U. S. N. Mus., xxii, p. 410, *Signiphora*)

Two females of this species were reared by the writer at Río Pie-

dras from *Pseudococcus citri* material on croton June 22, 1925, and a male was reared from similar material July 3, 1925.

Thysanus bifasciatus (Ashmead)
(1900 Proc. U. S. Nat. Museum, xxii, p. 411, *Signiphora*)

Four specimens reared in November 1925 by Francisco Sein from parasitized *Pseudococcus citri* placed in shell vials, have been compared by Mr. Gahan with the unique type of *bifasciata* and prove to be the same species. It is most probably hyperparasitic on either *Leptomastix dactylopii* or *Achrysopophagus seini*, both of which were reared from the same material. *T. bifasciatus* was described from a single female specimen collected by H. H. Smith on St. Vincent, and it is interesting to have more definite information concerning this distinctly West Indian species.

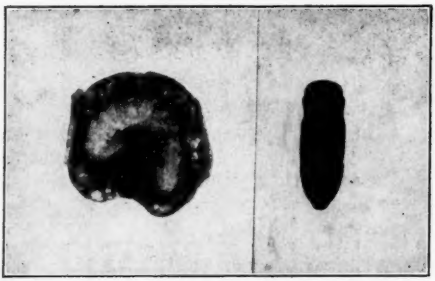

FIG. 6.—*Eupelmus saissetiae; (a)* full-grown larva *in situ; (b)* pupa, greatly enlarged

Thysanus flavus (Girault)
(1913 Proc. U. S. N. Mus., 45, p. 213, *Signiphora*)

A single female was reared by the writer from lignum-vitae material infested with *Aleurothrixus howardi* at Central Aguirre, Porto Rico, July 6, 1925.

Lecaniobius cockerelli Ashmead
(1896 Proc. Ent. Soc. Wash., vol. 4, p. 17)

A number of specimens were reared from *Saissetia oleae* on avocado at Río Piedras, May 26, 1925.

Eupelmus saissetiae Silvestri
(1915 Bol. Lab. Zool. Agr. Portici, vol. 9, p. 289)

The Black Scale, *Saissetia oleae*, is held in partial check in Porto Rico by parasites and apparently *Eupelmus saissetiae* is rather abundant. On June 11, 1925, many mature scales were found to contain grubs in various stages of development, one to a scale, the full-grown grub measuring 3.75 mm. A number were removed from the scale coverings and placed in a vial without food and pupated on June 13th.

Shortly afterwards the adults issued, showing a great variation in size, due most likely to the cutting short of their food supply.

Pseudoteroptrix imitatrix Fullaway
(1918 Proc. Haw. Ent. Soc., vol. 3, p. 464)

A single specimen reared by the writer from the mining scale, *Howardia biclavis,* on Acalypha at Río Piedras, November 24, 1924, has been determined by Mr. Gahan as this species. It is recorded as an abundant parasite of *Howardia biclavis* in Hawaii but out of a large amount of material placed in parasite cages in Porto Rico only the single specimen was obtained.

Plagiomerus cyanea (Ashm)
(1886 Entomologica Americana, IV, p. 156, *Comys*)

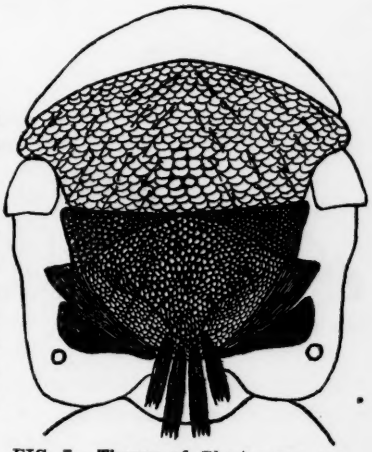

FIG. 7.—Thorax of *Plagiomerus cyanea* greatly enlarged, showing the flattened scales

This species is easily placed generically by the four-jointed funicle and the cluster of flattened scales at the apex of scutellum. One species of the genus, *P. diaspidis,* was reared in New Mexico from *Diaspis cacti,* and Girault (Ann. Ent. Soc. Amer., Vol. VIII, p. 280) stated that *Comys cyanea* Ashmead from Florida should be placed in *Plagiomerus* and is very much like *diaspidis* but has joints three and four of the funicle white. Mr. P. H. Timberlake, to whom the writer sent his material for study, writes that "it differs from the described species *diaspidis* Cwfd., *cyanea* (Ashm.) and *hospes* (Timb.) in having the scale-like setae extremely broad and also from *cyanea* in having the mesonotum much less brilliantly blue, and its pubescence dark instead of white." After considerable study and comparison with the type of *Comys cyanea,* Mr. Gahan and the writer decided that this material is most probably *cyanea* Ashmead. The type of *cyanea* from Florida is card-point mounted and the relative width of the scale-like setae is difficult to discern although they appear slightly narrower than in the Porto Rican material.

Female: Antennae nine-jointed, the pedicel longer than the first two funicle joints together; the funicle four-jointed, its second joint distinctly shorter than the others and only half as long as wide; hairs prominent. In slide-mounted specimens the scutellum is deeply and roundy reticulated, the mesonotum more coarsely and less distinctly so; from base of scutellar fold apex, arise a cluster of much-flattened, very broad scales and just above the fold on each side is an oblique row of three prominent setae. Mesonotum with rather long black setae. Wings hyaline, strongly iridescent, densely and finely ciliated over apical half, the hairless oblique streak very difficult to distinguish on account of the fineness and sparseness of cilia over the basal area; submarginal vein with seven prominent setae; marginal vein not punctiform, and the post-marginal short but distinct. Ovipositor very deeply seated, but with a short portion extending beyond abdomen.

Head and body blackish with decided metallic bluish-green reflections. Specimens mounted in balsam on slides show dark-brown. Antennae are pale yellowish, most of the pedicel, the first two funicle joints, and most of the first and last joint of the club, fuscous. Legs blackish, with following exceptions: the knees and apices of the front tibiae, basal half and apices of the middle femora and base and apical half of middle tibiae, the base and apices of the hind tibiae, and all tarsi, pale. The brown portions of the legs show coarse reticulation under high power.

FIG. 8.—Antenna of female *Plagiomerus cyanea* (Ashm.)

Length, .80–.90 mm.

Re-described from a series of card-point-mounted females and four individually slide-mounted females, all reared by the writer during June and July, 1925, from lignum vitae, infested with *Ceroplastes cirripediformis, Aspidiotus cyanophylli,* and *Aleurothrixus howardi,* collected at Central Aguirre, Porto Rico. Without very much question this species is a primary parasite of the wax scale.

THE GENUS *Aspidiotiphagus* Howard

This genus has been recently revised by the Italian Entomologist, Guido Paoli (Bol. della Soz. Ent. Italiana, Vol. 58, July 1926), and he now recognizes as valid two species and one variety, *citrinus* var. *agilior* Berl. Ashmead's *A. aleyrodis* as represented in the U. S. National Museum by three pin-mounted specimens is not an *Aspidiotiphagus* but is probably an *Encarsia.* Heretofore *A. lounsburyi* has been known only from the Island of Madera, and Liguria, Italy, where at the latter place it was introduced and established as a parasite of *Chrysomphalus dictyospermi.* It is therefore of interest to

record the presence of this species in the New World. Specimens of both typical *citrinus* and *lounsburyi* were submitted to Dr. Paoli who checked on the identification.

Key to Species of *Aspidiotiphagus*

First joint of club distinctly shorter than either of the apical two, submarginal vein always with a single seta, marginal setae 3–4---------- *lounsburgi* Berl. and Paoli.

First joint of club nearly as long as each of the apical two, submarginal vein with two setae, marginal setae 4–6-----
citrinus (Craw.)

Aspidiotiphagus citrinus (Craw.)

(1891 Destructive Insects, Sacramento, Cal.; *Coccophagus*)

The writer has examined in the U. S. National Museum slides containing specimens reared from *Aspidiotus aurantii* at San Francisco, Cal., April 1902, by Alex Craw. Without the original types, which are apparently lost, this material must be considered as typical and as authoritative as any. These specimens show nearly the entire adomen darkened and not distinctly banded as in the familiar drawing that has served to illustrate this species for so many years. They show the first joint of the club almost as long as either of the apical two, the submarginal vein always with two setae and the number of setae on edge of the marginal vein varying from four to five, the latter number being the rule.

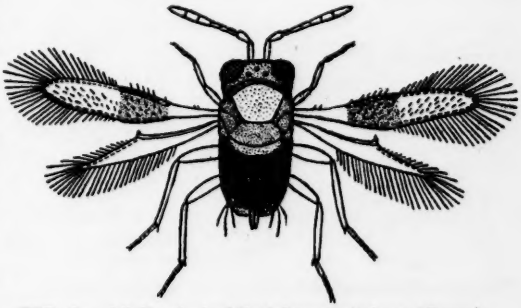

FIG. 9.—Adult of *Aspidiotiphagus citrinus* (Craw.)

Female: Head as wide as thorax; antennae eight-jointed, the scape long and fusiform; club elongate, the last two joints subequal and only slightly longer than the first, and miscroscopic elevations present as in figure; eyes large and prominent. Scutellum with two rather distinct pores. Forewings are rather wide and the anterior margin well-rounded; the marginal vein is furnished with four to five marginal setae, that number being variable, often a specimen having four marginal setae on one wing and five on the

other; the submarginal vein, however, always has two fine setae; the disc of the forewing with numerous cilia arranged in three or four more or less distinguishable rows and there is a bare area about the stigma.

Head and body brown with the exception of the vertex, lower two-thirds of mesonotum and the parapsides, all of which are yellowish. Antennae uniform smoky. Anterior wings with the marginal vein dusky, and with dark infumation or clouding beneath its length, extending across the entire width of wing. Legs pale yellowish.

Length of body, .36–.44 mm.; expanse, .920–1 bb.; greatest width of forewings, .08–.10 mm.;

Male unknown.

The above description is drawn up from numerous slide-mounted and fresh specimens reared from *Asterolecanium pustulans* on various hosts during 1925 at Río Piedras, Porto Rico; from *Diaspis carueli* on juniper, Newark, Delaware, October 16, 1925; and from *Chrysomphalus tenebricosus* on willow at New Orleans, La., February 11, 1926.

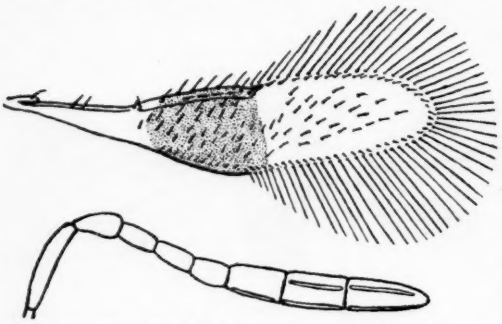

FIG. 10.—Forewing and antenna of *Aspidiotiphagus citrinus* (Craw.)

Aspidiotiphagus lounsburyi

(1916 Redia, XI, fasicle 1, p. 305, *Prospaltella*)

Readily distinguished from *Aspidiotiphagus citrinus* by its more yellowish color, the first joint of the club being only about half the length of the second joint, and especially by having only a single seta on submarginal vein.

Female: Head as wide as thorax, the eyes large and prominent. Antennae eigth-jointed, long and slender, especially the fusiform scape; pedicel distinctly larger and wider than the funicle joints which are all subequal in length; first joint of club only about half as long as the second and of equal width. Ocelli placed in equilateral triangle. Forewings long and narrow, narrower and more pointed at tip than those of *A. citrinus;* marginal cilia very long, those on hind margin distinctly longer than those on anterior margin; the

marginal vein furnished with three marginal setae, although some have four and there is a single submarginal vein seta.

The entire head and body is of a dirty yellow color, the posterior two-thirds of the mesonotum and the parapsides being the lightest in coloration. Some specimens are much darker, approaching more the coloration of *citrinus*. Eyes dark reddish brown. Ocelli distinctly carmine red. Antennae dirty yellowish. Forewings with infuscation across the width of the wing beneath the marginal vein similar to *citrinus*. The cilia on disc are fewer than in *citrinus* and arranged in two or three rows. Legs pale.

Male unknown.

Length, .30–.36 mm.; expanse, .68–.80 mm.; greatest width of forewing, .06 mm.

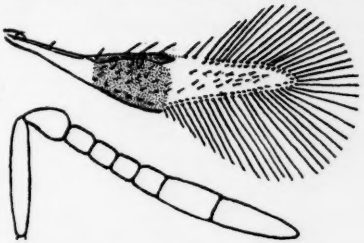

FIG 11.—Forewing and antenna of *Aspidiotiphagus lounsburyi* Berl. and Paoli

Above description made from a slide containing seven females and a slide containing four females reared by the writer from *Aspidiotus destructor* on plant at Río Piedras, Porto Rico, May 29, 1925; and four females on slide reared from scale material on citrus, Río Piedras, Porto Rico, May 21, 1925; six females on slide reared from *Diaspis pentagona* on mulberry June 5, 1925, at Río Piedras, Porto Rico. The writer has for comparison many specimens from the Island of Madera, reared from *Chrysomphalus dictyospermi* by Guido Paoli, June 1923.

NOTES ON PORTO RICAN THYSANOPTERA

By H. L. Dozier[1]

The writer is greatly indebted to Dr. J. D. Hood who has kindly confirmed or determined the species recorded in this short paper.

Franklinothrips vespiformis (Crawford)

Ten adults taken on guava foliage in association with *Selenothrips rubrocinctus* and the guava whitefly, *Aleurodicus minimus*, September 21, 1924, at Río Piedras. Also collected in bloom of cultivated rose May 24, 1925.

Aleurodothrips fasciapennis Franklin

From citrus material infested with Soft and Purple Scale, May 24, 1925, at Río Piedras.

Selenothrips rubrocinctus (Giard)

This species was present in the adult and last instar in large numbers September 18, 1924, attacking the underside of foliage of a muscadine grape imported from Florida on the experimental grape plot at the Station. While serious damage was done to the muscadine, other varieties adjacent were not attacked, including the native grape, Californian varieties, *Vitis amurensis* and the Carmen. On October 28th, this thrip was abundant on an imported variety of mango, on guava, and on almendra, *Terminalia catappa*. On No-

FIG. 1.—Typical work of the Cuban Laurel Thrips, *Gynaikothrips uzeli*, on "Laurel de India"

[1] Formerly Chief Entomologist of the Insular Experiment Station.

vember 1st it was found attacking young leaves of the mangosteen, *Garcinia mangostana,* and on the 5th the Burbank Thornless Blackberry in the berry plots was extremely badly infested and nearly completely defoliated. The Himalaya Raspberry, *Rubus ellipticus,* was also generally attacked and the Cuthbert Raspberry was very slightly infested. The native berry was not attacked.

Gynaikothrips uzeli (Zimm.)

At all seasons of the year this thrips may be found abundant, curling the leaves and growing tips of the "Laurel de India", *Ficus nitida* Thunb., wherever the latter occurs on the Island. Two predaceous anthocorid sucking bugs, *Macrotracheliella nigra* Parshley and *Cardiostethus* sp., were attacking this thrip in abundant numbers at Juana Díaz, February 11, 1925. Trees at San Juan were found heavily infested July 2, 1925.

Heliothrips haemorrhoidalis Bouche

Abundant breeding on leaves of an introduced plant, *Barringtonia speciosa,* at Río Piedras, May 24, 1925.

Frankliniella insularis (Franklin)

This is the most common species of flower thrips over the Island, attacking many different flowers—in blooms of *Canavali maritimus* on the beach at Santurce, January 6, 1925; abundant in blooms of "granadilla", *Passiflora quadrangularis,* June 17, 1925; in rose blooms at Río Piedras, May 24, 1925.

Frankliniella triciti (Fitch)

Taken in blooms of grape fruit at Trujillo Alto.

Haplothrips merrilli Watson

Specimens of what has been placed dubiously as this species have been obtained from parasite emergence boxes of scale and whitefly material as follows: numerous specimens from *Asterolecanium bambusae* material on bamboo, Río Piedras, May 31, 1925; one specimen from *Pulvinaria iceryi* material on sugar cane at Arecibo, May 31, 1925; one specimen from *Howardia biclavis* on Acalypha, Río Piedras, May 31, 1925; one specimen from *Ceroplastes cirripediformis* on passion vine; and a single specimen from *Aleurothrixus howardi* on lignum-vitae at Central Aguirre, July 22, 1925. The fact that this thrips has been reared in each case associated with either scale

or whitefly material would indicate that the species is most likely predaceous on the young.

Hoplandrothrips reynei Priesner

Several specimens of this large thrips issued from *Asterolecanium pustulans* material on *Cassia fistula* placed in parasite emergence cages, May 31, 1925, at Río Piedras. This species also is most probably predaceous on young scale and whitefly.

EDIBLE GARCINIAS AND POSSIBLE MANGOSTEEN STOCKS [1]

By P. J. Wester

PRELIMINARY REMARKS

The genus *Garcinia* includes some 210 or more species, mostly described from tropical Africa and the Indo-Malayan region, including New Guinea and the Philippines, which last-mentioned archipelago has 30 known species. In the south and east of the Malay Archipelago the range of the genus extends to Australia, whence four species have been described, to New Caledonia which has contributed 12, and to Fiji with four species of which one also has been found in the Tonga Islands, the eastern limit of the genus. The northermost limit for these plants is Hongkong, where two species have been found. To the westward 16 species of *Garcinia* have been described from Madagascar, and 80 from tropical continental Africa where they are scattered from coast to coast. Five species of *Garcinia* previously described from tropical America are now referred to other genera.

Most species of *Garcinia* perhaps prefer a moist climate throughout the year, though many also thrive in regions with pronounced dry seasons. While the vast majority grow at low and medium elevations, some are also found at altitudes ranging from 1,300 to 2,000 meters.

Practically all *Garcinias* are trees, some of which are reported to attain a height of 20 or more meters. A few are shrubs, while at least two climbers have been described. The habit of a considerable number is still unknown.

The leaves are opposite, rarely ternate, simple, thick and leathery, or thin. The flowers are polygamous or dioecious, solitary or in

[1] The success recently attained in grafting the mangosteen on the *Bunag* has prompted a review of the experiments made to find a stock for the mangosteen, and the literature related to *Garcinias*, in an attempt to determine in view of past experiences what other species might be sufficiently closely related to the mangosteen to be worth experimenting with for stock purposes, and to assemble for the convenience of experimenters with these interesting plants the information available about species with edible fruits, hitherto widely scattered in many publications difficult of access. Incidentally the paper also serves to call attention to the lack of detailed knowledge relative to the habitat, climatic requirements, and the fruits of many species with alimentary potentialities. It is a pleasure to acknowledge my obligations to Governor Carl M. Moore of Sulu, for herbarium material of *G. mooreana*, and to Dr. S. Youngberg and Mr. A. W. Prautch, Bureau of Agriculture, Manila, P. I., who furnished the photographs for the accompanying plates.

fascicles, terminal or axillary, with four to five sepals and petals, many stamens in the male flowers, and a one- to many-celled ovary.

The mangosteen is the best known species in the genus, and one of the most highly prized fruits in the world. Indeed, a suggestion for improvement of this excellent fruit is a tax on the imagination. Not only is the snowwhite flesh exquisitely flavored, and very attractive to the eye contrasted against the pink lining of the rind as the fruit is opened, but it is provided with a thick, fibrous shell or container for protection that makes the fruit a better shipper than most tropical fruits. And yet, hasn't some one said that there is a fly in every ointment, or words to that effect?

An aristocrat among fruits, the mangosteen tree is, one might say, highly temperamental, fastidious in its environmenal requirements, and difficult to handle in the nursery. It thrives only in a hot, moist climate, with fairly abundant rainfall of equal distribution throughout the year. The seeds are perishable and rapidly lose their viability unless properly cared for. The plant has a weak root system and is of very slow growth in the nursery stage. Hence the mangosteen, notwithstanding its excellence, has never become widely distributed, and still is grown to any considerable extent only within a restricted area in Java and the Malay peninsula, with small orchards in Burma, Siam, Indo-China, and Ceylon. It is rarely seen in the western Indian peninsula. Semi-cultivated it occurs in Jolo, in the Sulu Archipelago, Philippine Islands, where it thrives to perfection. Less than a score of trees are in bearing in all the other islands of that Archipelago though the climatic conditions are favorable in many districts. Occasional trees have fruited in Hawaii, Ecuador, and the West Indies, including Porto Rico, but all attempts at a general dissemination of the mangosteen have failed.

EXPERIMENTS WITH GRAFTING AND STOCKS

In the Western Hemisphere the mangosteen first fruited in 1875 in Trinidad, B. W. I. After many fruitless attempts to raise plants from the seeds had been made, the late W. H. Hart, then superintendent of the Botanic Garden of that island, as early as 1888 tried to inarch the mangosteen on other, more vigorous and fast-growing species of *Garcinia* but without success. His experiments were repeated in Jamaica with the same results. Through the initiative of Dr. David Fairchild, agricultural explorer in charge of foreign seed and plant introduction of the Bureau of Plant Industry, United States Department of Agriculture, experiments in inarching the

mangosteen on other species of *Garcinia* and related plants were begun about 1902 by the late G. W. Oliver, and later have been continued by Mr. Edward Goucher, now superintendent of the Bell Plant Introduction Station, Glen Dale, Md. As a result of his work Oliver in 1910 published a bulletin in which he claimed to have found certain species successful stocks for the mangosteen. To quote:

"The most promising species of *Garcinia* for use as stock plants for the mangosteen are *G. tinctoria, G. morella,* and *G. livingstonei* in the order named. *Platonia insignis,* so far as the work has progressed, is a very promising stock from one to three years after germination, and if it will grow under the conditions suitable for the mangosteen it may turn out to be the best stock of all those tried."

Aside from those mentioned, Oliver says he experimented with about 20 species, among which he mentions *G. cornea, G. hanburyi, G. fusca, G. loureiri, G. sizygifolia, G. speciosa, G. spicata, Calophyllum calaba,* and *C. inophyllum.* However, while there were no difficulties in getting a union between stock and scion, later it was found that after it had been severed from its own roots the mangosteen refused to accept the stock though in some instances it remained alive for a year after severance. In the moist greenhouse atmosphere the stumps of such grafted mangosteen scions frequently developed aerial roots that descended into the soil and re-established their own root systems.

Experiments made by the writer more than ten years ago at the Lamao Experiment Station, Philippine Islands, showed that *Calophyllum inophyllum* could easily be shield-budded. Shield buds of the mangosteen inserted on this plant and on *G. venulosa* made a good union, and the buds remained alive for some three months before they died. Cleft grafts of mangosteen on *G. dulcis* and *G. binukao* likewise failed, though the former species was shield-budded on itself, and the latter cleft-grafted on itself without difficulty.

In 1918 in Parang, Jolo, Sulu Archipelago, and in Iwahig, Palawan, Philippine Islands, I came across a *Garcinia* called Bunag[1] (in Palawan) that had the characteristic features of the mangosteen except that the fruit was smaller, reddish instead of purplish, with sharply acid instead of subacid flesh like the mangosteen. In fact, it was so similar to the mangosteen that it occurred to me that here was the long-sought-for stock for the mangosteen, if it existed. Seeds

[1] From material brought him, Mr. E. D. Merrill, then botanist of the Bureau of Science, Manila, P. I., identified the Bunag as *G. benthami* Pierre, under which name it is described and figured in Bulletin No. 39, The Food Plants of the Philippines. However, from the description and plate of *G. Benthami* in Flore Forestiere de Indo-China by Pierre, it would appear that *Bunag* is not that species.

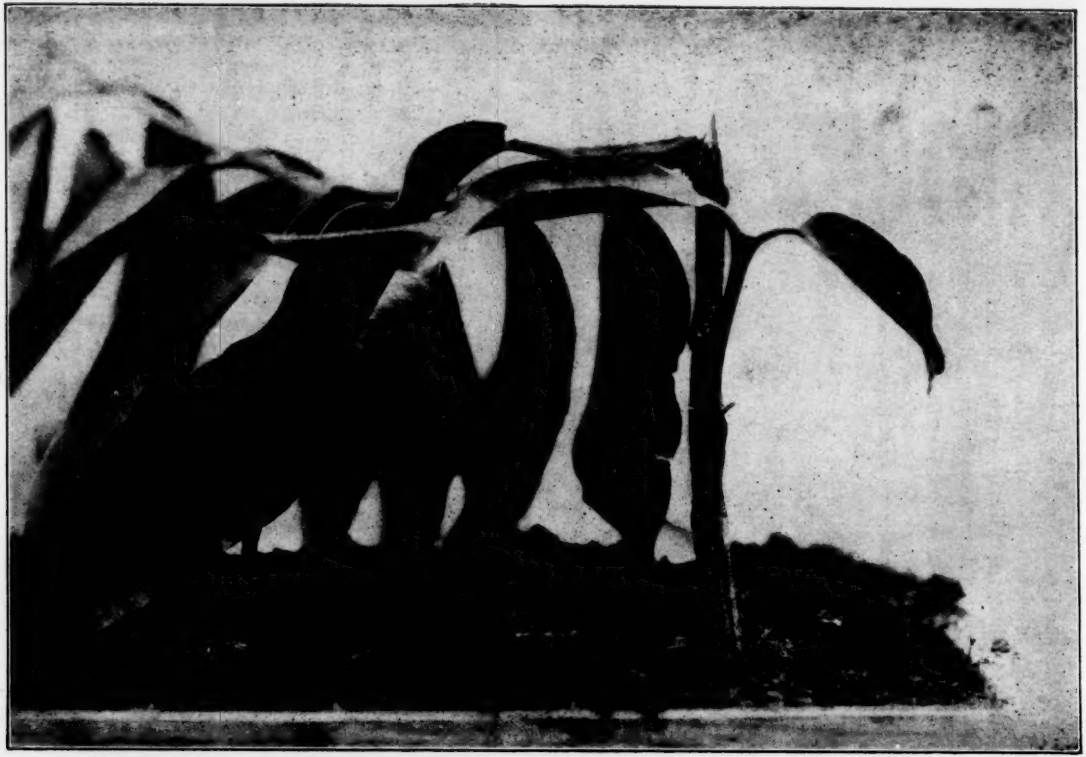

FIG. 1.—A shield-budded plant of Banati, *Garcinia dulcis*, related to the mangosteen. Experiments made at the Lamas Experiment Station, P. I., show that plants of this family are easily shield-budded and cleft-grafted.

were accordingly obtained from Palawan and propagated by the Bureau of Agriculture at the Lamao Experiment Station with the idea of trying the plants as stocks for the mangosteen. However, owing to the frequent changes of superintendents of the Station, the purpose for which the Bunag plants were grown was lost sight of, and nearly all were distributed as they grew up. One plant found its way to the garden of Mrs. R. M. McCrory, Manila, where quite by accident I came across it in 1923, when it had grown into a small handsome tree. A dozen or so shield buds of the mangosteen were inserted in the top of the tree, most of which made a good union. But the tree was such a handsome one that, not knowing whether or not the buds would make a successful growth, I hesitated to cut back the top sufficiently to force the buds into growth, and they finally died. In the meantime a few *Bunag* plants were obtained by Mr. John R. Schultz, Calauan, Laguna, and in May, 1924, I inarched a small mangosteen plant on one of the *Bunag* seedlings, which rapidly made a good union. Fig. 2 shows the grafted plant about two years after the inarch was made. It was then nearly a meter high, and in perfect condition.

While the *Bunag* grows wild in localities with an evenly distributed rainfall, in Manila it has shown itself well adapted to a climate having a long, dry season. The tree shown in Fig. 3 is about 5 years old from planting the seed. Of course, the outcome is by no means certain, but from present indications the *Bunag* used as a stock for this fruit promises to hasten by several years the coming into bearing of the mangosteen as compared with its being grown on its own roots, and to extend the culture thereof over vast regions where hitherto this has been impossible for climatic reasons.

POSSIBLE STOCKS FOR THE MANGOSTEEN

From the experience gained in previous experiments it is apparent that only rather close relatives are acceptable as stocks by the mangosteen, and the theory is advanced that the position of the flowers, whether terminal or axillary, and the character of the pericarp, whether fibrous and crustaceous or fleshy, indicate the species that are sufficiently closely related to the mangosteen to be worth trying for stock, and those others that are so far removed from this fruit that a successful union of the two is beyond probabilities.

Trees with fruits having a fibrous, crustaceous or shell-like, inedible pericarp are believed to be most likely to prove successful stocks. Except in the *Bunag* whose flowers are unknown, this character is always associated with terminal flowers. To this group

FIG. 2.—Mangosteen successfully grafted on another plant, the Bunag. This is of vigorous growth and thrives under climatic conditions under which the mangosteen fails to grow.

belong the mangosteen, *G. hombroniana*, and *G. penangiana*. Apparently *G. cornea* and *G. celebica* also have fruit characters in common with the mangosteen, for Roxburgh describes the fruit of the former as "covered with a dark purple, juiceless bark," and Heyne says of the fruit of the latter that it is similar to the mangosteen. Undoubtedly there must be other species belonging in this group among the large number of which the descriptions are so incomplete that they fail to convey a definite idea of the fruit character, and another large number of which the fruit is still unknown. Two other species particularly worth investigation are *G. delpyana*, said to have a fruit with spongy pericarp—an expression sometimes used about the mangosteen—and *G. dioica*, said to have a fruit like the mangosteen. Both species are described as having terminal as well as axillary flowers.

A little further removed from the mangosteen are those species bearing terminal flowers, but with fruits having a more or less fleshy, frequently edible pericarp. Until more is known of their behavior it is believed that they should be considered possible stocks for the mangosteen. Those with inedible or little-known fruits belonging in these two groups will presently be enumerated. Species that belong in this class having edible fruits are included in the list of edible *Garcinias*.

Still more remote from the mangosteen is a third group of species in which the flowers are produced in the axils of the leaves as well as at the end of the twigs. With perhaps rare exceptions they are believed not sufficiently closely related to the mangosteen to afford material for stock. Finally, there is a fourth group in which all flowers are axillary. All of the several species in this group that have been tried for stocks have failed, and it seems improbable that it will yield stocks for the mangosteen.

In the following species the flowers are terminal, and fruits have been collected, but as will be noted, the descriptions thereof are too incomplete to furnish clues as to whether or not the pericarp is crustaceous. Most fruits, if not all, probably are inedible. The plants are suggested for trial as mangosteen stocks.

Garcinia echinocarpa Thw.

A tree 12 to 15 meters high, native of Ceylon, where it is found up to an elevation of 1,800 meters; therefore, some forms are likely to be quite cold-resistant, a valuable feature under Florida conditions. The leaves are 7.5 to 15 cm. long, lanceolate-oblong or obovate, acute or retuse, thick and leathery. The flowers are pale

FIG. 3.—Bunag seedling in Manila about five years old, showing its vigor and adaptability to climatic conditions unendurable to the mangosteen.

yellow, the male sometimes axillary, but the female terminal and solitary. The fruit is 4 cm. long, subglobose, the surface dark red and covered with short, broad protuberances somewhat like *Litchi chinensis*.

G. latissima Miq.

A plant found in Celebes and Halmahera. The leaves are 30 cm. long and 16 cm. broad, and leathery. The fruit is subglobose, 4 to 6 cm. in diameter, with a fleshy pericarp and white pulp, containing one seed. The habit of the plant is unknown, but judging from the large leaves it is of robust growth.

G. maingayi Hook. f.

A tree 12 to 18 meters tall, native of the Malay Peninsula. The young branches are thick and 4-angled. The leaves are elliptic-oblong, obtuse, shining on both sides, 11 to 17 cm. long and up to 8 cm. wide. The flowers are waxy white. The fruit is roundish, 5 to 6 cm. in diameter, 4 to 6-celled.

G. microstigma Kz.

A shrub about two meters tall, native of the Andamans. The leaves are elliptic to elliptic-oblong or lanceolate, subacute, up to 10 cm. long. The female flowers are solitary. The fruit is roundish, up to 5 cm. across; the pericarp smooth, red and thin; the pulp containing 2 or more seeds.

G. montana Ridl.

A small tree 5 meters tall, found at an elevation of 900 meters on Mt. Ophir, Malay Peninsula. The leaves are lanceolate, bluntly acuminate, and thickly coriaceous. The female flowers are solitary, greenish yellow. The fruit is flask-shaped and beaked, 2 cm. long.

G. multiflora Champ.

A shrub, native of Hongkong. The leaves are obovate, obtuse, up to 7 cm. long, and 3 cm. wide. The fruit is subglobose, smooth, 2.5 cm. in diameter, 1 to 2-seeded, the seeds being similar to those of the mangosteen. The plant is probably quite cold-resistant.

G. schefferi Pierre

A tree 10 to 15 meters high, native of Indo-China. The leaves are oblong or elliptic, rounded to short acuminate, leathery, 8 to 13 cm. long, and 3 to 6 cm. broad. The female flowers are solitary. The fruit is oval, about 3 or more cm. long, smooth, ripening in September.

G. travancorica Bedd.

A very attractive tree of medium size, found in Travancore, India, at elevations from 900 to 1,500 meters. The leaves are narrow-oblong to sub-spatulate, obtuse, dark green and shining, up to 10 cm. long. The female flowers are solitary. The fruit is inedible. The plant is probably quite cold-resistant.

In the following species the fruit is not known, but they have terminal flowers and therefore are believed to be worth while experimenting with as stocks for the mangosteen:

Garcinia baillonii Pierre. BORNEO
Garcinia bassacensis Pierre. INDO-CHINA
Garcinia crassiflora Jum. & Perr. MADAGASCAR
Garcinia gracilis Pierre. INDO-CHINA
Garcinia krawang Pierre. BORNEO
Garcinia kurzii Pierre. ANDAMAN ISLANDS
Garcinia lucens Pierre. BORNEO
Garcinia madagascariensis Baill. MADAGASCAR
Garcinia multibracteolata M. PHILIPPINES
Garcinia mungotia Pierre. NEW CALEDONIA
Garcinia murdochii Ridl. BORNEO
Garcinia nitida Pierre. BORNEO
Garcinia pancheri Pierre. NEW CALEDONIA
Garcinia quadrifaria H. Bu. TROPICAL WEST AFRICA
Garcinia riedeliana Pierre. CELEBES
Garcinia sorsogonensis Elm. PHILIPPINES
Garcinia trianii Pierre. BORNEO

The fruits are unknown, but botanists who have examined other parts of the plants regard *G. malaccensis* Hook. f., from the Malay Peninsula; *G. speciosa* Wall., from Burma and the Andamans; *G. wichmannii* Lbch., from New Guinea; *G. melleri* Baker, and G. *pauciflora* Baker, both from Madagascar; and *G. vieillardii* Pierre, from New Caledonia, as being very closely related to the mangosteen, and so are in line for trial for stocks for this fruit.

EDIBLE GARCINIAS

The mangosteen is by far the most important fruit in the genus, but there is a large number of species the fruits of which are eaten by the inhabitants of the countries where they grow, several of which have been domesticated, and are cultivated to some extent by the natives. The remarks relative to the edible qualities of a number of the fruits in addition to the descriptions of the plants by various botanists would indicate that they are worthy of more attention than

has been accorded them. To the plant breeder they present a large virgin field of more than ordinary interest. Not a few have terminal flowers, of which some, at least, may be found to be good stocks for the mangosteen.

G. afzelii Engl.

A plant of unknown habit, found in Guinea and Sierra Leone. The leaves are oblong-elliptic, acuminate, and rather thin. The fruit is roundish, 1.5 cm. or more in diameter, smooth, yellow, and edible.

G. atroviridis Griff. ASAM GELUGUR

A wild and cultivated very graceful tree with pendulous branches attaining a height of 10 to 18 meters, native of the Malay Peninsula, where it is found from sea level up to 500 meters altitude. The leaves are 15 to 23 cm. long, and 5 to 7 cm. wide, oblong-lanceolate, abruptly acuminate, bright pink when young changing to dark green, shining on both sides. The flowers are terminal, the female solitary, large, and blood red. The fruit is sub-globose, 7.5 cm. or more long, orange yellow, smooth, with a firm-textured but not tough, fleshy, acid pericarp, enclosing the rather thin translucent pulp, divided into 9 or 10 locules. Too acid to eat out of hand, stewed with sugar the fruit is excellent according to H. N. Ridley, for many years director of the Botanic Garden in Singapore, who says that it is the best soft-rinded *Garcinia* in the Malay Peninsula.

G. bancana Miq. KELABANG

A tree, 10 to 20 or more meters high, native of wet swampy forests in Banka, Sumatra, and the Malay Peninsula. The leaves are broadly obovate-lanceolate, rounded to mucronulate, 12 to 20 cm. long, the petiole winged. The flowers are axillary. The fruit is ovoid, green, and fleshy, and is eaten by the natives in the Dutch possessions.

G. benthami Pierre. ROI

A tree 20 to 25 meters tall, with pyramidal crown, native of Indo-China. The leaves are oblong or elliptic-oblong to lanceolate, short acuminate to obtuse, up to 13 cm. long in old, and up to 18 cm. long in young trees. The flowers are terminal, yellow, the female solitary. The fruit is about 4.5 cm. in diameter, obpyriform, smooth; the persistent style concave, and tiara-shaped; the pulp in which the 5 to 10 seeds are embedded is white, acid, and of agreeable taste. The fruit ripens in April. The tree should be tried as a mangosteen stock.

G. binucao Cy. BINUKAO

A tree 15 or more meters tall, with drooping branches, of wide distribution under varying climatic conditions at low elevations in the Philippines, succeeding well where the dry season is pronounced. The leaves are obovate to elliptical, pointed, smooth and leathery, 5 to 12 or more cm. long. The flowers are axillary. The fruit is about 4 cm. in diameter, subrotund, flattened at the apex, sometimes nippled at the base, smooth, greenish yellow. The pericarp is quite firm, but like the scant pulp fleshy and very acid, and is eaten with fish by the natives. The 6 to 8 seeds are enclosed in bony shells. The fruit ripens in May and June. The binukao has been sucessfully introduced and fruited in Miami, Florida.

G. cambogia Desr. HILA ARADAL

A small, erect, handsome tree with drooping branches, native of the lowlands up to an elevation of 600 meters in Ceylon and western India. The leaves are 5 to 12 cm. long, oblong-elliptic or lanceolate, rather thin, dark green and shining. The male flowers are axillary, the perfect ones sometimes terminal. The fruit is about the size of an apple, the basal half with 6 to 8 grooves lengthwise, the apex flat and depressed and the surface yellowish or reddish. The pericarp is fleshy, and together with the 6- to 8-celled pulp of pleasant flavor, and eaten as a substitute for tamarinds with fish. The Singalese also dry the fruit and use it for flavoring curry. The fruit ripens in June and July.

G. celebica L. KIRASA

A rather rare tree up to 15 meters high, native of the Malay Archipelago at low elevations where it occurs wild and cultivated. The leaves are elliptic to oblong-elliptic, rounded, shining, and up to 22 cm. long. The flowers are terminal. The fruit is roundish, somewhat flattened, in the cultivated forms up to 5 cm. in diameter. While the descriptions do not refer to the character of the pericarp, the fruit is said to be similar to the mangosteen, though with less, rather acid, white edible flesh, 5- to 6-celled. It ripens in June and July. The tree should be tried as a stock for the mangosteen.

G. cochinchinensis Cy.

A handsome tree with erect trunk, native of Indo-China, where it is cultivated. The leaves are ovate-oblong and subacute. The flowers are axillary. The fruit is subglobose, 5 cm. across, reddish yellow, 6–locular, fleshy, acid and edible.

G. conrauana Engl. NTU

A tree 20 to 30 meters in height, native of Kamerun. The leaves are elliptic, leathery, up to 9 cm. long. The fruit is 3 cm. in diameter, subglobose, reddish yellow, with orange-colored edible pulp. The seeds also are edible. The fruit ripens in June.

G. cornea L. HUSSUR

Originally described from the Malay Archipelago, this plant also has been collected in Burma. According to Roxburgh who described it from trees obtained from the Malay Islands, growing in Calcutta, it is a handsome tree, in Burma attaining a height of 18 meters. The leaves are oblong, short acuminate, shining, 10 to 15 cm. long. The flowers are terminal, pale yellow. The fruit is nearly round, about 3.5 cm. in diameter, covered with dark purple, juiceless bark, the seeds up to 4, embedded in white, subacid pulp of pleasant taste. The fruit ripens in May and June. Hooker remarks that the pericarp is spongy as in the mangosteen, bright red in color, and that the pulp is very acid. Therefore, notwithstanding the failure reported by Oliver it is believed that the Hussur should be tried again as a stock for the mangosteen. The species is considered a synonym of *G. celebica* by some authors.

G. costata Hemsl.

A rather large tree, sometimes exceeding 20 meters in height, found at 750 to 900 meters elevation in Perak, Malay Peninsula. The leaves are elliptic, acute, thinly coriaceous, and 16 to 38 cm. long, and up to 16 cm. wide. The flowers are pale yellow tinged with red, terminal, the female solitary. The fruit is roundish, flattened, 5 cm. long and 7.5 cm. in diameter, with many deep longitudinal grooves, pale rose to red, and edible. It should be tried as a stock for the mangosteen.

G. cowa Rxb. COWA

A handsome tree up to 18 meters tall, with slender drooping branches, from the Andamans and Bengal to Burma and Assam. The leaves are broadly lanceolate, acute, thick and shining, 7.5 to 12 cm. long. The flowers are terminal and axillary. The fruit is of the size of a small orange, roundish, depressed at the apex with a nipple-like projection in the center, and 4 to 8 longitudinal grooves, dark yellow, the pericarp fleshy and of good flavor like the pulp which contains 4 to 8 seeds. The fruit ripens in June and July, and is said to make a remarkably fine preserve.

G. cumingiana Pierre. MALABU

A small tree up to 10 meters high, found at low and medium elevations, in part in regions with a long dry season, in northern Luzon, Philippine Islands. The leaves are oblong or elliptic-oblong, acuminate, leathery, and up to 20 cm. long. The flowers are terminal, solitary, and yellow. The fruit is roundish, somewhat flattened, smooth, up to 5 cm. in diameter, fleshy, acid, and edible. The *Malabu* should be tried as a stock for the mangosteen.

G. delpyana Pierre. TRAMENG

A tree 10 to 18 meters tall, native of Indo-China. The leaves are oblong to linear-oblong or lanceolate, leathery, and 10 to 20 cm. long. The male flowers are terminal or axillary, the hermaphrodite solitary. The fruit is globose, about 3 cm. in diameter, smooth, yellowish, and has a spongy pericarp. The pulp in which the seeds are embedded is of pleasant taste, and divided into 6 to 7 locules. The *Trameng* should be tried as a stock for the mangosteen.

G. dioica Bl. TJEURI

A very characteristic tree up to 18 meters high, with erect trunk and spreading branches, found throughout Java below an altitude of 1,200 meters, common in many districts but nowhere cultivated. The leaves are rather small, oval to lanceolate, acuminate and thin. The flowers are terminal and axillary. The fruit is subglobose, somewhat flattened, depressed at apex, up to 3.5 cm. long, and up to 4 cm. in diameter, pale yellow, the pulp 6- to 10-loculed, and of refreshing flavor. In foliage and habit the tree does not appear to be closely related to the mangosteen, but the fruit is said to be similar to it and its trial as a stock might be worth the while.

G. dives Pierre. PILDIS

A small slender tree, 10 or more meters tall, of wide distribution under widely varying climatic conditions at low and medium elevations in the Philippines. The leaves are rather small, elliptic-lanceolate and pointed. The flowers are produced in the axils of the leaves. The fruit is roundish, 2 cm. in diameter, fleshy and edible.

G. dulcis Kz. BANITI (P. I.), MUNDU (Malay)

A small tree 9 to 15 meters high, of wide distribution at low and medium elevations succeeding well even where the dry season is pronounced, native of the Philippines, Burma, the Malay Peninsula and Archipelago. Cultivated in Java, and recently domesticated in the Philippines. The leaves are oval to elliptic and oblong, thick

and leathery, 12 to 20 or more cm. long. The flowers are axillary. The fruit is 5 to 7 cm. in diameter, in shape resembling a small pointed peach, smooth and yellow, the pericarp fleshy and edible like the juicy pulp in which 2, rarely 3 seeds resembling large beans are embedded. Both the pericarp and the arils are quite acid, but tender in texture and of pleasant flavor, and make excellent jam. Trees with subacid fruits occur now and then.

G. fusca Pierre. BUA LUEUR

A shrubby tree 5 to 8 meters high, found in Indo-China. The leaves are oval to linear-oblong, leathery, 8 to 15 cm. long. The flowers are axillary. The fruit is roundish to ovoid, with a pointed apex, smooth, fleshy, acid and edible, ripening in October.

G. globulosa Ridl. KANDIS

An erect tree 18 or more meters tall, common in the forest in the Straits Settlements. The leaves are elliptic, acuminate, 5 to 7.5 cm. long. The flowers are terminal and axillary. The fruit is round, 1.3 cm. in diameter, orange-colored, pulpy, and of pleasant flavor. The tree is abundantly productive.

G. griffithii T. And. SIBANGOR (Sum.) KANDIS GAJAH (Mal.)

A large, rather common tree 15 to 18 or more meters tall, found in Sumatra and the Malay Peninsula below 300 meters elevation. The leaves are remarkably large, up to 45 or more cm. long and 18 cm. wide, ovate or ovate-elliptic, obtuse, leathery and shining. The flowers are axillary. The fruit is 5 to 7.5 cm. in diameter, pomiform, flattened at apex, greenish yellow, juicy, acid and edible.

G. harmandii Pierre REMIR

A low-branched tree of compact growth 6 to 10 meters high, native of Indo-China. The leaves are obovate and leathery, 4 to 10 cm. long. The flowers are terminal, the female solitary. The fruit is subglobose, flattened, up to 2 cm. across, purplish, the pulp sweet and of pleasant flavor, containing 1 to 3 seeds. The fruit ripens in April. Pierre, speaking of the eating quality of the fruit, suggests that it merits the attention of horticulturists. The tree should also be tried as a stock for the mangosteen.

G. hombroniana Pierre BRUAS, MANGIN HUTAN

A tree resembling the mangosteen, 9 to 18 meters tall, wild or planted at low elevations in the Nicobar Islands and the Malay

Peninsula, particularly mentioned as growing in sandy soil near the sea. The leaves are ovate-elliptic to ovate-oblong, short acuminate, somewhat glossy above, 9 to 15 cm. long, and 5 to 7 cm. wide. The flowers are dioecious, terminal, cream colored, and smaller than in the mangosteen. The fruit is similar in shape to the mangosteen but smaller, 5 cm. in diameter, the pericarp red, crustaceous and fibrous, but thinner than in the mangosteen, the 6-loculed pulp white, juicy and acid, and said to have the flavor of the peach. Ridley was so impressed with the quality of the *Bruas* that in an article published already in 1902 he said that it "would very much improve the common mangosteen if it could be crossed with it." Though it would seem improbable that the quality of the mangosteen could be improved by crossing it with another plant admittedly its inferior, nevertheless, the hybridization of the mangosteen and this and other of its more vigorous relatives with a view of producing hybrids of greater vigor than this fruit cannot be urged too strongly. New flavor combinations would be obtained in this way, and hybrids might also be produced that would prove serviceable stocks. Altogether, it is a fascinating problem. Being so closely related to the mangosteen, undoubtedly this tree could be easily grafted on the *Bruas*.

G. indica Cy. KOKAM, KATAMBI

A small slender tree with drooping branches, native of western India, cultivated around Bombay and in Mauritius; also introduced into the West Indies, including Porto Rico. The leaves are elliptic-lanceolate, acute to acuminate, thin, dark green, 7 to 10 cm. long. The male flowers are terminal and axillary, the hermaphrodite are solitary and grow at the ends of the twigs. The fruit is roundish, from 4 to 5 cm. in diameter, and purplish like the acid but agreeably flavored pulp which is divided into 4 to 8 locules. An edible fat is extracted from the seeds. The fruit ripens in the spring. The plant is sufficiently closely related to the mangosteen to deserve a trial as a stock.

G. kerstingii Engl.

An arborescent shrub to a small tree, found from sea-level up to an elevation of 500 meters in Togoland and Guinea. The leaves are oblong-lanceolate to elliptic-lanceolate, leathery, 10 to 15 cm. long. The fruit is globose, 1.5 cm. in diameter, yellowish to pinkish, 2-seeded, and is eaten by the natives. It ripens over a large part of the year.

G. lanceofolia Rxb. KIRINDUR

A small tree native of Burma and Assam, in the latter country cultivated for the fruit which is much esteemed by the native inhabitants. The leaves are narrow lanceolate, acute, 8 to 9 cm. long. The flowers are axillary or terminal, the female solitary. The fruit is about the size of a small plum, obovoid, orange-yellow, containing 6 to 8 seeds. It ripens in July.

G. lateriflora Bl. DJAWURA (Java), KARIIS (P. I.)

A slender tree up to 15 meters high, of wide distribution from sea-level up to 800 meters altitude in the Philippines, in central and western Java up to 1,000 meters. The leaves are elliptic to elliptic-lanceolate, acuminate, thin, 10 to 24 cm. long, and 5 to 8 cm. wide. The flowers are axillary. The fruit is subglobose, flattened, 2.5 to 3.5 cm. in diameter. In the Philippines the pulp is juicy, acid, and of pleasant flavor. In Java the fruit is reported to be sweet and commonly eaten, and Koorders and Valeton commend it to the attention of horticulturists. It ripens in December.

G. livingstonei T. And. PAMA, IMBE, MOKONONGA

A shrub to a small tree, native of tropical Africa. The leaves are opposite or ternate, broadly elliptical or obovate-elliptic, blunt or notched, up to 9 cm. long. The flowers are axillary. The fruit is oblong, up to 5 cm. long, red or purplish, the pericarp fleshy, juicy edible, and together with the pulp used in making a fermented liquor by the natives. Seeds 2 to 3. The *Pama* has been successfully introduced and fruited in south Florida.

G. loureiri Pierre. BUANHA

A tree 10 to 15 meters tall, native of Indo-China where sometimes it is cultivated. The leaves are oval-oblong or oblong-lanceolate, leathery, 8 to 12 cm. long. The flowers are axillary or terminal. The fruit is short oblong, 5 cm. long, and 4 cm. in diameter, grooved corresponding to the locules which vary from 6 to 10. The pericarp is yellow on the surface and reddish inside. The pulp is white, acid and of agreeable taste. In preparing it for storage the pericarp is sliced, dried and salted, and then prepared for food, or used for flavoring in place of vinegar. The fruit ripens in June.

G. macrophylla Miq. SELAPAN

A tree 20 to 30 meters high, native of Sumatra. The leaves are large, oval to elliptic, acute to blunt, 33 to 38 cm. long, and 15 to

19 cm. broad. The flowers are axillary. The fruit is pomiform, 4-loculed, acid, and eaten by the natives.

G. mangostana L. MANGOSTEEN

A small tree rarely more than 9 meters in height, believed to be native of the Malay Archipelago or Peninsula. The leaves are oblong-elliptic, acuminate, thick and leathery, shining above, 17 to 23 cm. long. The flowers are terminal, red, the female solitary or in pairs, 5 cm. in diameter. The fruit is about 6 cm. in diameter, globose, a trifle flattened, smooth, reddish or purplish. The snow-white, exquisitely flavored, subacid pulp is divided into 5 to 8 locules, enclosed in a crustaceous, fibrous, shell-like pericarp about 8 mm. thick. The mangosteen is unexcelled as a dessert fruit, and makes a delicious preserve boiled (including the seeds) with sugar. On its own roots the mangosteen thrives only on the lowlands, perhaps up to an altitude of about 600 meters, where the rainfall is fairly ample and well distributed throughout the year. If the hopes are realized relative to the use for stocks of the Bunag and perhaps other species, the culture of the mangosteen might be extended over a great part of the Tropics. Definite information at what age seedling trees come into bearing is lacking. Some authors claim that they bear at the age of 7 to 10 years, while others say that 15 to 20 years' growth is required before fruiting. Certainly the growth of young plants is very slow, and under the most favorable circumstances they probably do not bear until 8 to 10 years old. A full-grown tree will bear from 200 to 500 fruits, and maximum crops of 1,200 fruits have been reported. Two crops per annum are not uncommon.

G. merguensis Wight. LULAI (Malay), SONVE (Annam)

An ornamental tree up to 15 or more meters high, from Burma and the Malay Peninsula to Indo-China, where it occurs from sea level to an altitude of 1,400 meters. The leaves are lanceolate-elliptic to ovate, acuminate, thinly coriaceous, 5 to 10 cm. long. The flowers are axillary. The fruit is roundish, somewhat flattened, up to 2 cm. in diameter, and has a fleshy pericarp. The fruit is eaten in Indo-China.

G. mestoni F. M. B.

A small, erect, slender, graceful tree 7 or more meters tall with drooping branches, found in Queensland. The leaves are narrow lanceolate, undulate, dark green and glossy, 5 to 10 cm. long. The fruit is globose, flattened, 5 to 7.5 cm. in diameter, green, smooth,

the pericarp fleshy, and together with the juicy, 8-celled pulp of pleasantly acid flavor.

G. mindanaensis M. KABANGLA

A small, slender tree attaining a height of about 10 meters, found at medium altitudes in Mindanao, Philippines. The leaves are 12 to 18 cm. long, and 4 to 8 cm. wide, pointed. The red flowers are borne in the axils of the leaves. The fruit is up to 3 cm. in diameter, smooth, acid and edible.

G. nigro-lineata Pl. KANDIS (Malay)

A slender tree 10 to 14 meters tall, native of Malaya, Burma and Siam. The leaves are lanceolate or ovate-lanceolate, somewhat leathery, russet colored beneath, 12 to 20 cm. long. The flowers are auxillary. The fruit is ovoid, about 3.5 cm. long, orange yellow, and has a soft, fleshy, acid, pericarp, and sweet pulp of pleasant flavor. The tree is abundantly prolific.

G. oliveri Pierre. TROMENG

One of the largest trees in the genus, 20 or more meters tall, native of Indo-China. The leaves are 10 to 27 cm. long and 4 to 8 cm. wide, and pointed. The flowers are axillary or terminal. The fruit is short oblong, compressed at both ends, 4 to 5 cm. long, and 3 to 4 cm. in diameter, smooth, reddish, the pericarp fleshy, and together with the 9- to 10-celled pulp very acid, but nevertheless quite sought for as a food by the natives. The fruit is common in the market from June to September, and is sliced and preserved with salt.

G. paniculata Rxb. BUBI-KOWA

A tree about 13 meters high, found in Bengal and the foot hills of the eastern Himalayas, ascending to 1,350 meters. The leaves are oblong-lanceolate to obovate, acuminate, thin, shining, 15 to 23 cm. long. The flowers are terminal. The fruit is about the size of a large cherry, round, yellow, the pulp of good flavor resembling somewhat the mangosteen, containing 4 seeds. The fruit ripens in July. The plant should be tried as stock for the mangosteen.

G. parvifolia Miq. KANDIS

A tree of upright growth and slender branches 12 to 15 meters tall, native of the lowlands of Sumatra and Singapore. The leaves are elliptic to oblong-lanceolate, acuminate, dark green, thinly coriaceous, 6 to 14 cm. long. The flowers are axillary. The fruit is of

the size of a cherry, elliptic, orange yellow, fleshy and acid, and is eaten by the natives in Sumatra. One to 3 seeded.

G. pedunculata Rxb. TIKUL

A stately tree of rapid growth attaining a height of 20 meters, native of Bengal and Sylhet. The leaves are quite large, oblong to elliptic-oblong, somewhat leathery, 28 to 40 cm. long, and 10 to more than 13 cm. wide. The flowers are terminal. The fruit is subglobose, sometimes more than 10 cm. in diameter, yellow, the fleshy pericarp sometimes more than 2 cm. thick, and like the juicy, 8- to 10-loculed pulp very acid but of pleasant flavor. The tree is cultivated, and the fruit is used in curries and for making "ades". Sliced and dried the fruit keeps in good condition for a long time. The fruit ripens from April to June. The *Tikul* deserves a trial as a mangosteen stock.

G. planchoni Pierre.

A tree 15 to 20 meters high, native of Indo-China. The leaves are oblong to oblong-elliptic or obovate, 18 to 24 cm. long, with prominent lateral veins. The flowers are terminal or axillary. The fruit is roundish, grooved lengthwise, with a few wart-like protuberances on the surface, 7 to 8 cm. in diameter, greenish yellow. The pericarp is quite thick, fleshy, acid, and like the acid, 8-celled pulp, edible and of agreeable flavor. The fruit ripens over a large part of the year. The natives slice and dry the fruits in the sun with or without salt, which so conserved keep a long time. Pierre remarks that the fruit merits cultivation.

G. prainiana King. CHERAPU

A small tree about 9 meters high, native of the Malay Peninsula. The leaves are elliptic-oblong, leathery, dark green, shining, 12 to 22 cm. long. The flowers are terminal. The fruit is subglobose, flattened, up to 5 cm. in diameter, yellow and smooth, with a fleshy acid pericarp, and subacid edible pulp. According to Ridley the Cherapu is eaten like the mangosteen, for which the plant deserves a trial as stock.

G. rubra M. KAMANI

A small tree attaining a height of 10 meters, found at low elevations from northern Luzon to Mindanao, Philippine Islands. The leaves are elliptic to elliptic-obovate, acute to acuminate, thin, and 6 to 12 cm. long. The flowers are axillary and bright red. The fruit

is subrotund, flattened, up to 3 cm. in diameter, smooth, yellowish to red, fleshy, acid and edible.

G. subelliptica M. DANEALAN

A tree 10 to 15 meters high, found in eastern Luzon immediately back of the beach. The leaves are broadly elliptical with rounded ends, thick and leathery, about 10 cm. long. The flowers are white, and borne in the leaf axils. The fruit is subrotund, flattened, 5 cm. in diameter, yellow, fleshy, acid and edible, containing 3 or more large seeds.

G. tetranda Pierre. TAMIL

A small tree found at low and medium altitudes from southern Luzon, through Samar and Leyte to Mindanao. The leaves are 12 to 15 cm. long, pointed or rounded at the ends, and rather thin. The small axillary flowers are followed by roundish, flattened fruits, 3 to 4 cm. in diameter, yellowish to reddish, smooth, with scant, sour but edible pulp.

G. tinctoria W. F. Wight. MATAU

A symmetrical tree up to 15 or more meters high, native of India to the Malay Peninsula and the Andamans. Introduced in Porto Rico where it has fruited well. The leaves are quite large, linear-oblong to oblanceolate, acute or acuminate, leathery, dark green and shining, 20 to 45 cm. long, and up to 10 cm. wide. The flowers are axillary. The fruit is 5 to 7 cm. in diameter, roundish and pointed at the apex in the manner of a peach, smooth, bright yellow, very acid but of pleasant flavor, containing 1 to 3 large seeds. The tree is robust, and of rapid growth, and is very productive sometimes yielding two crops per year. The fruit is a good keeper.

G. venulosa Cy. KATURY

A tree attaining a height of about 15 meters, of wide distribution at low and medium elevations in the Philippines, thriving also in districts with a prolonged dry season. The leaves are oblong, acuminate, leathery, 20 cm. or more in length. The flowers are small, axillary or terminal. The fruit is 4 to 6 cm. in diameter, subrotund, somewhat flattened, smooth, greenish, with acid flesh, eaten with fish by the Filipinos.

G. vidalii M. KANUBI

A tree up to 15 meters high, found in regions with a well-distributed rainfall at low and medium altitudes, from northern Luzon to

Mindanao. Seldom cultivated. The leaves are broadly oval, dark green, glossy, thick and leathery, 10 to 20 cm. long. The flowers are white, and grow at the ends of the twigs. In appearance the fruit somewhat resembles the mangosteen, but has a fleshy, acid pericarp, is yellowish in color, and has acid edible flesh, enclosing 10 or more seeds. It should be tried as a stock for the mangosteen.

G. wentzeliana Engl. MDOGOLO

A stout, woody climbing vine, native of tropical Africa. The leaves are oblong to obovate-oblong, leathery, shining, 10 cm. long, and up to about 5 cm. wide. The fruit is roundish, about 1.5 cm. in diameter, sweet, juicy and of agreeable flavor. It ripens in January.

G. gerrardi Harv. UMBINDI

A large shrub or a small tree about 4 meters tall, found from Cape Colony to Natal and Zululand. The leaves are broadly lanceolate, oval or elliptic, acute, glossy above, 2.5 to 5 cm. long. The flowers are terminal. The fruit is roundish to ovoid, up to 2 cm. long, black, with edible flesh, one-seeded. The fruit is produced sparingly. The Umbindi, which probably is quite frost-resistant, should be tried as a stock for the mangosteen.

G. barrettiana n. sp. KADIS

A small tree 5 or more meters tall with slender branches, found in the Cotabato valley, Mindanao. The leaves are rather small, thin and pointed, 7 to 10 cm. or more long. The fruit grows in the axils of the leaves, and is up to 6 cm. in diameter, markedly oblate, with a shallow cavity at apex; the surface smooth, light orange in color; the pericarp soft, fleshy, acid, and edibe; the pulp surrounding the seeds light orange in color, juicy, subacid, and of good flavor, divided into 6 to 8 locules, the seeds quite similar to those of the mangosteen. The fruit ripens in December and January, and can be eaten out of the hand with relish, but probably could be best utilized made into preserves like the mangosteen. Abundantly productive.

G. mooreana n. sp. BUNAG

A handsome tree of pyramidal habit attaining a height 6 meters or more, native of Jolo and Palawan, in which latter island it is found about Iwahig, where it is known as *Bunag*. The leaves are elliptic to elliptic-ovate, or ovate-oblong, acute at base, acute to short acuminate at apex, coriaceous, 15 to 21 cm. long, 7.5 to 11 cm. wide, the petiole about 15 mm. long. The fruit is similar to a mangosteen, except that it is somewhat smaller, is red in color, and has a thinner,

but fibrous, crustaceous pericarp; the flesh is white and sharply acid, of agreeable flavor, but too sour to be eaten out of the hand. It would probably make a good preserve boiled together with the seeds in sugar. Ripens in the latter part of July and August. As previously noted the mangosteen has been successfully grafted on the Bunag.

GARCINIAS AS ORNAMENTALS

Like the mangosteen, many species of *Garcinia* are very handsome trees, and can be used to great advantage for decorative plantings in parks and gardens. The best oramental species is perhaps *Garcinia andersonii* Hook. f., with its large leaves, 30 to 60 cm. long, and up to 22 cm. broad, and large pomiform fruits, which is described as "by far the noblest species in the genus". It is a native of Malacca.

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